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Plastics

Dealing with the Manufacture, Uses and Potentialities of Plastic Materials

Vol. IV NOVEMBER, 1940 No. 42

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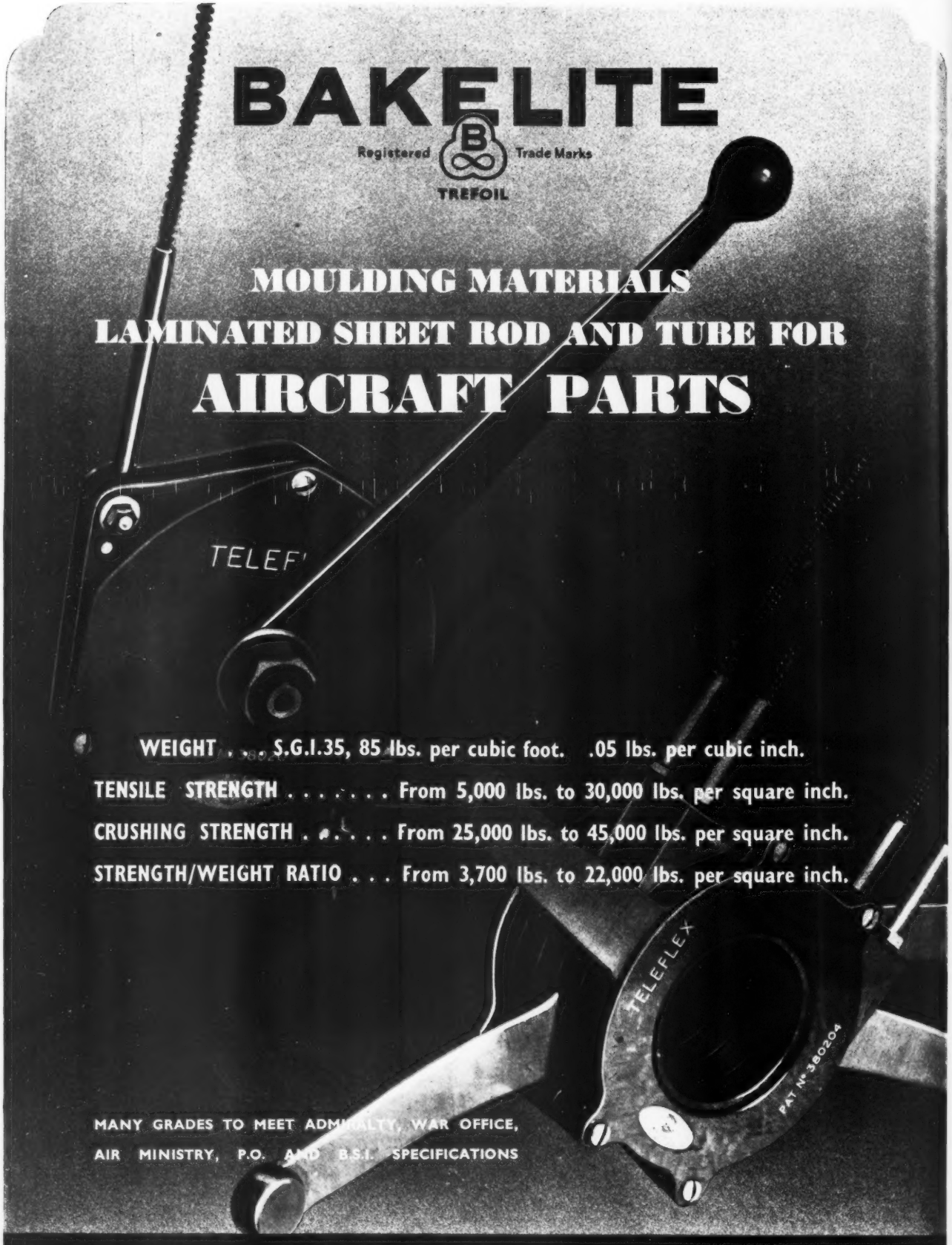

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Vol. IV. No. 42 NOVEMBER, 1940

Plastics

Dealing with the Manufacture, Uses and Potentialities of Plastic Materials

Proprietors - TEMPLE PRESS LIMITED
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Editor - - M. D. CURWEN, B.Sc., A.I.C.
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PLASTICS FOR REFRIGERATION

SOME years ago we suggested that refrigerator engineers might find it worth their while examining plastics in sheet or moulded form as a constructional material for the purpose of heat or rather cold insulation. There was a good reason for this suggestion, for it rather stares one in the face that whereas most forms of insulation are obtained by uniting two different elements, namely a metal holding structure packed inside or outside with the insulating element, we have in plastics a solid form often strong enough for the structural purpose in view and possessing of itself reasonable insulating properties.

The main problem is, how " reasonable " are these insulating properties and how do they compare with those of the best-known insulators already in use for refrigeration work?

At first sight they do not appear promising as first-class insulators. Harold Tongue in his book " Chemical Engineering " (Chapman and Hall, Ltd.) gives a list of the best-known types and their thermal conductivities. As they are in B.T.U.s, we have taken the liberty of converting the figures into the centimetre-gram-second scale to conform with the figures we have for plastics, and hope that our conversion factor is substantially correct.

Tongue's figures for thermal conductivities thus are:—

Expanded rubber	0.00008
Corkboard	0.000098
Hair felt	0.000105
Wool felt	0.000165
Slag wool	0.000140

Plastics vary considerably in thermal conductivity, the following being approximations only:—

Phenol-formaldehyde mouldings ...	0.0005
Urea formaldehyde mouldings ...	0.0007
Laminated phenolics	0.0005
Cast phenolics	0.0004
Polystyrene	0.0002
Cellulose plastics	0.0005

To complete the comparison we may add the figures for metals:—

Iron	0.01
Copper	0.08

Thus there leaps to the eye this interesting fact, that although plastics are inferior, as at present constituted, to the normal insulators, and in fact if we may so compare them, conduct heat or what is the same thing, " cold," some three to seven times more rapidly than the latter, yet, on the other hand, plastics are 20 to 50 times better insulators than iron, which is so often used for refrigerator bodies and door-casings. We have therefore to our hands a structural material with insulating properties of considerable value and withal of a strength which would conform to most refrigeration demands.

It is heartening to report that refrigeration engineers are now realizing the importance of plastics for their special sphere. Already panels of laminated sheet, moulded handles, etc., have been employed in household units, but the most important advance is reported in *Modern Plastics* of September, 1940. This takes the form of the installation of large " phenolic " moulded sliding door frames and rails in Hussman-Ligonier commercial refrigerators, upon which we shall elaborate in our next issue. Some of these door frames are as large as 19 ins. by 28 ins., and they are stated to conform admirably with the physical properties demanded of them.

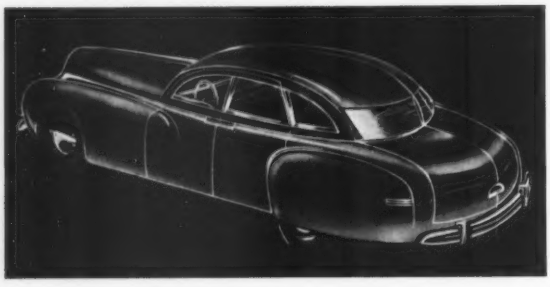
We hope that plastics for refrigeration will one day be the subject of a really scientific survey which up to the present they have not been. For there is no reason why special plastics should not be devised for the job, and thermo-plastics as well as thermo-setting materials could come into the picture. Moreover, the problem of type of filler must be examined. For example Kapok has never yet, we believe, been considered as such. The fibre is in form that of a hollow tube and possesses a thermal conductivity of 0.00009. Impregnated or mixed with synthetic resin it might make a very suitable laminated sheet or moulding powder.

It seems strange that some of the thermo-plastics with their low thermal conductivities and other advantages of transparency and stability at low temperatures have not been seized upon as suitable materials for insulation in the home of refrigerators—the United States of America. Perhaps, too, we shall see one day an expanded type of thermo-plastic filled with myriads of air-cells and yet strong enough to withstand considerable rough treatment.

Of interest, too, is a new material called Luxoid, made by Thermolux Glass Co., Ltd., which appears to be glass fabric impregnated with a cellulose plastic. Although it has been suggested as a replacement for window glass, it has obvious possibilities as an insulating medium.

The Plastic Car

SOME time ago Mr. George W. Walker, a well-known Detroit industrial designer, envisaged the plastic car of the future in the very attractive drawing shown below, which we first published in our May issue. It has now been reproduced in an American journal, which also gives the very cheering news that "no painting would be necessary and that fading and chipping are impossible, because the colour shade is moulded into the substance—that is, the body. Curved windshields and rear vision windows are made of transparent plastics."



Now, without wishing to detract from Mr. Walker's effort, for it is indeed a very fine design, this lovely vision flounders in a mass of sticky questions that arise, the most important of which is, of what plastic is the car to be made? To date, from the strength point of view only one or two types have appeared probable and only one or two have been used on a large experimental scale for making bodywork. The probables are the laminated type, which has actually been employed experimentally, and the flock impregnated with resin emulsion, which, so far as we know, has not been used. Our knowledge of the use of soya-phenol-formaldehyde resins by the Ford works is too little to make comment upon the process or the applications.

So far, then, only the laminated veneer impregnated can be considered until such time when the plastics industry is ready with much stronger materials which can be moulded from the powder.

The laminated type, however, scarcely conforms to the hopes of "no paint, no fading and no chipping." Incidentally, we are at a loss to explain why the writer of the aforesaid notice should imagine that the colours used in plastics cannot fade with time like any other colour, nor explain the expression, "chipping is impossible because the colour is moulded right into the substance." We think we know what he means to say.

However, to return to laminated plastics. These, as at present made, certainly require a painted surface, in which case chipping will reveal the usual brown colour of the laminated material beneath. We doubt whether impregnation with pigmented or coloured solutions of resin will prove of much value. On the other hand, beautiful decorations could be made by introducing a coloured top layer in the laminates. This is, of course, already done for wall decorations.

We come then to another branch of plastics, which, although at present seemingly impossible of use, is yet worthy of thought for future developments. We refer to thermo-plastics, and here, for the moment, we shall not consider their greatest drawback—high price—which may damn them for ever, but merely consider them as possibles.

Thermo-plastics are, from some few points of view, the ideal materials for motorcar construction. The ease with which large shapes can be moulded without high pressure or temperatures, their transparency (or their coloured opacity as required) would, indeed, produce a "no-paint job" and chipping would only reveal the same colour throughout. Repairs would be simpler and even a "car-owner" technique for simple repairs might one day be formulated. Most plastic technicians feel sure that somewhere the ideal thermo-plastic is waiting for us—with the transparency of cellulose acetate or acrylic resin, with somewhat greater strength than a vinyl acetate or chloride and their resilience, and a slightly higher "melting" temperature than existing thermo-plastics.

We do not see why even cellulose plastics should not be strengthened. First, the reinforcing of acetate sheet has scarcely been examined except for window glass and the like, and, again, it is not inconceivable that new cellulose esters of greater strength than cellulose acetate should not be made. A very illuminating graph recently published by Dr. N. de Bruyne showed that the tensile strength of cellulose derivatives decreased with the increase in length of the substituted side chain. In other words, this means that cellulose acetate has a greater tensile strength than cellulose butyrate, which, in turn, is stronger than cellulose stearate. The cellulose micelles are forced farther apart as the substituted side chains increase.

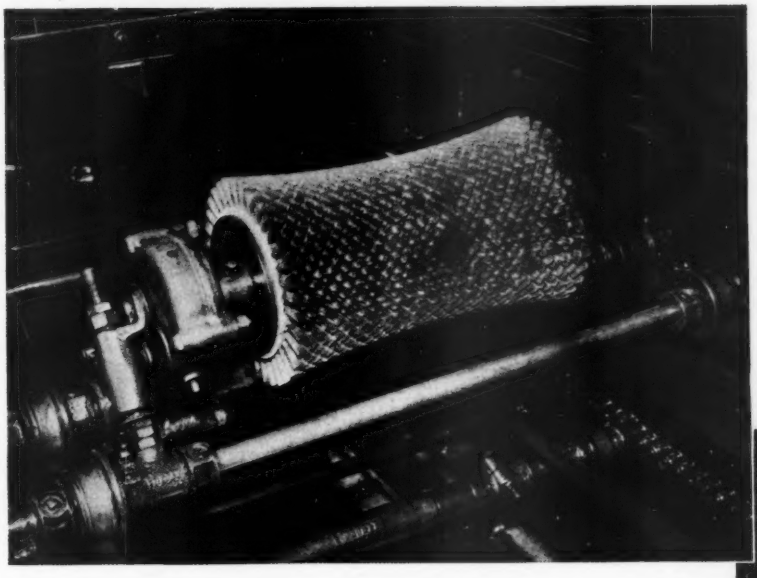
This information rather begs a new set of experiments, viz., those using an entirely different set of acids, such as naphthenic acid or furoic acid, for combining with cellulose. Both these acids are of the five-membered ring type, are very stable and occupy very small spaces compared with the long straight chain acids. The combination with naphthenic acid might conceivably lower the water-absorption capacity of the finished plastic.

Editorial Tail Piece

ALMOST day by day we get advice in this office of Empire war news: of the presence of powerful Canadian, Australian, New Zealand, Indian and other forces in Great Britain, the Near East and on the seas and in the air; of the magnificent gifts from a thousand towns, from poor people in the African Continent, of rich princes in India, of lonely islanders in the Pacific. It should make this country very humble and determined more than ever to deserve the great service that has been offered so freely.

No wonder the Germans and many other peoples fail to understand the Empire. Hitler, with visions of past bickerings and apparent cataclysms within the British Empire, foresaw its easy breaking up. Whether it is that blood is thicker than water, or that, after all, there is something inherently humane, in spite of bad mistakes, in the confederation, the result is the same. We must never forget what the Empire has done for us.

NYLON ENTERS INDUSTRY



This brush with nylon bristles, especially designed for cleaning filter screens at the Milwaukee Sewage Disposal Plant, is exceeding all endurance records for such a job.

WHEN the first news of nylon broke upon the world it was sufficiently exciting to hear that this new plastic, made by pure synthesis from comparatively simple raw materials, was revolutionizing the textile and the tooth-brush industries. Some with quick perception foresaw beyond the tooth-brush demands into industries where the need for strong bristles was even greater.

Industrial brush manufacturers have used materials of many kinds from many sources—chiefly hog bristles from India, Russia and China; palmetto from Florida palm trees, and tampico from Mexican cacti. Hog bristles have dominated the field for centuries, but supplies have been uncertain in recent years because of disturbed conditions abroad. Nylon is coming into extensive use, not only because of the scarcity and rising prices of natural bristles, but also because of its advantageous properties. The chemically made bristles are strong, elastic and uniform in diameter. They will not split or become brittle. Since they absorb, at a slow rate, only one-fifth as much moisture as the best available natural bristle, they retain their stiffness for a long time. Nylon bristles can be cut into bundles of any required length and steam sterilized or dyed for special purposes. Their superior resistance to abrasion and to the action of many chemicals has been proved by laboratory tests.

The *Du Pont Magazine* of September, 1940, tells of the application by one of their engineers of nylon bristles to a set of washer brushes operating in a hot-water spray to remove powder from continuous plastic sheeting. Moisture absorption and abrasion had previously limited the average life of natural bristles to six weeks, but the nylon-bristled brushes, installed in November, 1939, still show no signs of failure. While the initial expenditure for these brushes was greater, their longer life has already resulted in impressive savings which increase proportionately each day.

In the bottling industry, high-speed machines wash thousands of bottles hourly. The brush bristles are

(Above) A Hoover vacuum cleaner with nylon-bristled vibrator brush.

(Below) Close-up of the new-type brush with bundles of bristles cut to the proper length ready for installation at the factory.

subjected to extreme abrasion, to constant flexing at bottle necks, and to hot alkali solutions. Bottlers who have installed nylon brushes report that the bristles last from three to twenty times longer than those previously used, with resultant long-range economies.

In the textile printing industry, serviceable brushes are required to convey dyes from shallow vats to the engraved metal rolls from which the designs are printed on fabrics. The abrasive action of the rolls and the chemical reaction of the dyes shorten the life of tampico bristles, in some instances, to only a week. In contrast, the first nylon brush has yet to be re-bristled, after more than a year in operation. Moreover, in addition to its resistance to deterioration, nylon has the advantage of being washable, so that a brush containing these chemically made bristles can be used in a variety of different coloured dyes.

In the home as well as in industry, nylon bristles are now replacing less satisfactory types. After extensive tests proved their superiority, nylon-bristled vibrator brushes were installed in one model of the Hoover vacuum cleaner. With the machines operating at speeds up to 3,000 r.p.m., the new bristles were found to last over four times longer than horsehair.

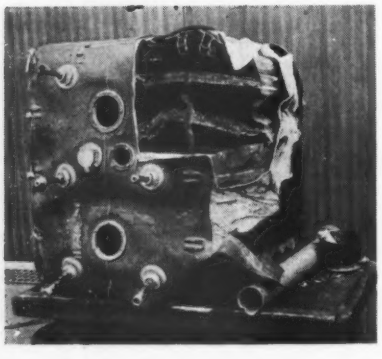
A sewage plant in Milwaukee, Wisconsin, where the aeration disposal method is employed, provides a most unusual application for nylon brushes. During operation, the soluble material passes through a screen, while the insoluble must be brushed away from the face of the screen. The average service life of brushes equipped with animal bristles is about a year. A set of nylon brushes installed in March, 1939, after eighteen months' service, is functioning as well as ever.

Similar histories of nylon's improved performance can be told for spotting brushes, used by dry cleaners where strong solvents quickly break down natural bristles; for edging brushes, used in the baked enamel industry where resistance to abrasion is essential; for wheel brushes, operating in water where nylon's low absorption increases the service life of the bristles.

With such an initial experience record, there seems little room for doubt that nylon's "higher original investment for lower ultimate cost" will make sweeping changes in the brush industry.

Bullet-proof Tanks

In our April, 1940, issue we made mention of the "bullet-proof" tanks or, rather, self-sealing tanks, carried in the German aeroplanes. We stated that they were made up of a structure of the vulcanized-fibre type with layers of alternating natural and synthetic rubber as an outer covering. More exact information is given in the October 11 issue of our companion journal *The Aeroplane*, whose editorial staff has been allowed to examine some of the German aircraft that have recently been brought down in this country almost intact. The details given in the following notes are official.

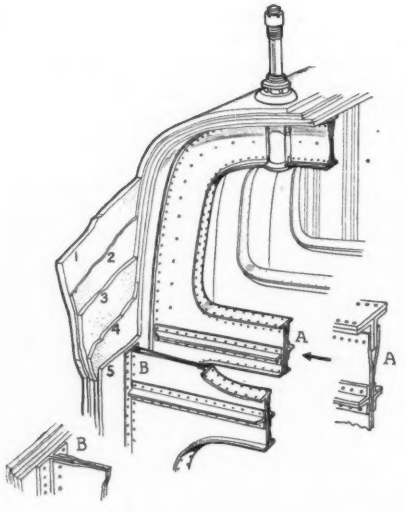


Left: The upper photograph shows the exterior view of a 1,200-litre petrol tank with its rubber covering. The lower photograph shows the tank cut open to expose the inner structure. Right: The drawing gives a more detailed aspect of the make-up of the tank.

As previously stated, the containing tank is of fibre, but that it is of "vulcanized" fibre is not stated. There are four layers outside this, which are clearly shown in the accompanying drawing: (1) An outer covering of black vulcanized rubber $\frac{1}{4}$ in. thick; (2) a layer made up of very thin sheets of yellow untreated rubber varying from one to five in number; (3) yellow raw rubber bonded to (4) grey crêpe rubber $\frac{3}{8}$ in. thick; (5) is the fibre inner casing.

The drawing also shows A and B, the fibre baffle plates to prevent excessive surging of the petrol in the tank. The only metal part in the whole construction is the connection for installation shown at the top. The photographs show a 1,200-litre tank from the centre section of a Junkers Ju 88 complete in its rubber covering and sections to show the construction.

It seems strange that, according to the information given us, no synthetic rubber has been used in the construction. We asked the pertinent question as to how the examiners of the tank knew there was none, since the distinction between raw natural rubber and synthetic is not easy. We were informed, however, that the Air Ministry officials appeared definite on this point. It may be that synthetic rubber has not the self-sealing properties of the natural material.



Plastic Moulds for Rubber Ware

By FORDYCE JONES

In the search for cheaper production it has been suggested that were it possible to utilize moulds made from moulding powders an important step forward in certain types of simple repetition work would be possible. Obviously the moulding powders or the moulds from them would be modified to conform with requirements hitherto divorced from plastics, namely reasonable heat conductivity. The following notes are by a well-known rubber technologist whose experiences offer valuable suggestions.

OUR Editor recently suggested the use of plastic moulds to replace metal for various repetition production.

It appears that such moulds would be useful for cold produced articles such as plaster and other poured or pressed compositions, paper mâché, wax and even metal alloys, fusible at low temperatures, but when it comes to the practice of using them with high temperature, together with high pressure, various problems have to be faced.

My notes refer particularly to the use of plastic moulds in the moulding of heat vulcanized rubber goods. It is, of course, well known that there are many cold processes used in the production of rubberware, some of these directly from the rubber latex, pure or compounded, and in such cases one has to remember the possible adverse action of ammonia or other stabilizing re-agents used in the latex mix or the effect of the use of various activators, accelerators, anti-agers and other compounding materials.

There is no doubt that plastic moulds could be successfully used in pressing out soft rubber compounds, either as blanks or semi-finished mouldings, prepared for self-vulcanization at room temperature, or for finish in hot air or chemical curing after forming.

In the usually operated method of rubber moulding, where great heat and high pressure is necessary, transfer of heat is a simple matter through metallic moulds, but difficulties face us in the use of resin compounds, which are poor conductors of heat.

Metal Powder and Plastics

The Editor has suggested the use of metallic powders in the plastic mix and there is no doubt that such powders will greatly increase the heat conductivity of the resin compounds, but they may have a depolymerizing effect by their power of absorbing and holding heat, and unless they are absolutely inert as regards chemical activity with sulphur and other chemicals used in rubber compounding they will soon not only prove useless but destructive.

It has already been pointed out in this discussion that the slightest trace of copper or manganese in the mould or mix is ruinous to rubber; perhaps by oxidation and the formation of sulphides. It is known that a percentage of even .01 per cent. of copper or manganese in a rubber compound will rapidly cause it to perish, and cases have been known where manganese pockets in steel moulds have continued to mark rubber and ultimately destroy it by contact. This has happened over a long period in some cases and the only cure was to use the mould on a light-coloured stock from which the pocket could be identified, and then to have it drilled out of the mould and the hole refilled and surface finished.

Curiously, brass fillings, as evidenced by our Editor, and even brass parts of moulds, have not been found so injurious in the vulcanization of rubber, this is perhaps because the zinc in the brass gives partial protection, for zinc is quite neutral with rubber and also the continued use of mould lubricants would help to insulate the rubber from direct contact with the injurious copper base.

Copper is certainly the ideal metal for heat conductivity and it appears that it can be used with vulcanized rubber with the use of a " de-activator." It is reported that vulcanized rubber may be preserved from the action of sulphur, by incorporating in it, along with a small amount of customary anti-oxidant, a small amount of an organic compound obtained by condensing a polyamine, one mol. with at least two mols. of an o-hydroxy substituted aldehyde. It is remembered that copper wire for electric conduction is usually insulated from the vulcanized rubber covering either by tinning or by a layer of pure unvulcanized rubber.

Suitability of Metals

Perhaps the best metals to use are chemically pure aluminium or zinc powders, on the other hand, tin or steel powder might be useful if it could be obtained in sufficiently fine division. Lead powder could perhaps be used in part and might be worth experimenting with, and, although it is subject to surface oxidation, its heat conductivity is appreciated.

By the way, lead powder may be made by stirring heated lead with powdered whiting or dry clay until it cools, and then washing and sifting out the finer particles. Lead powder has been prepared in this way for use in rubber and asbestos packings with considerable success. It has also been used as a filler with rubber, where added weight is required.

Suitably compounded resin moulds might possibly be finished off on their surface either by electro plating with chromium, on a suitable base, or by having the surface treated with sprayed metal, to be subsequently polished. I believe that base metal moulds have been treated with the spraying of suitable surface metals on the Continent and by subsequent treatment have produced a very fine wearing surface. It appears, however, that if a suitable mould could be made by repetition in a compounded plastic, that the ideal surface could be made suitable for the electro deposition of a non-corrosible metallic surface.

The use of powdered metal in rubber certainly increases its heat conductivity and in certain cases will cancel out the di-electric properties of rubber and make it conductive. When metallic powders have been added to hard rubber, ebonite or vulcanite, they have thus altered its properties, but where continued heat is used as in a heat-operated mould, have tended to its earlier destruction.

Their effect on resins such as phenol-formaldehyde have yet to be determined by experiment.

Some time ago experiments were made to produce imitations of textiles in rubber. Articles such as lace table mats were treated with shellac to give hardness and keep their shape. These were then insulated from adhesion by surface treatment and from these hard rubber moulds were made. They were found quite suitable for production at low temperatures and low pressure, but under ordinary factory working conditions they disintegrated after 30 to 40 mouldings, on a five minute cycle at 306 degrees F.

It would be most interesting to see if better results could be obtained from suitable heat-resisting plastic resins. The process certainly offers possibilities for original and decorative production.

With reference to pressure, it is certain that plastic moulds would suffer under the high pressures used in the rubber industry and required high ratios of production would not be obtained with low pressures and much lower temperatures, but the moulds can be prepared to withstand pressure by the insertion of metallic bearings running through the mould from platen to platen, Fig. 1. These could best be made as corner

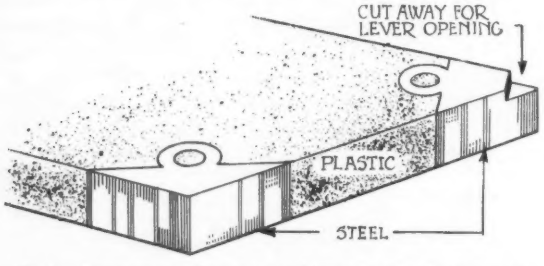


Fig. 1.—Arrangement showing metal bearings in a plastic mould.

pieces where possible, especially prepared with cut-away edges to allow the mould to be easily opened with a lever without wear to the plastic part.

Dowels, if required, could be let into the metal corner parts or moulded into the plastic in production in the usual way; an ideal design for a dowel is given in Fig. 2, which if of metal should be fitted with a case-hardened bush. The ordinary rounded end parallel-sided dowel, Fig. 3, should now be relegated to the past as this improved design not only saves wear, is easily cleaned, but permits the mould to be very easily opened with a short lever lift.

I am quite sure that some enterprising research worker in the plastic industry would find profitable and interesting time spent in such work as is here suggested, both in combining various metallic powders, perhaps including plumbago, with various plastics and noting not only their physical effects, but their ageing properties under heat and pressure, and also in their resistance to mechanical stresses, which are important as a part of profitable production.

The rubber industry is looking for repetition moulds which can be accurately and economically produced as well as having a fine surface finish and with the addition of engraved decorations, when required.

As is well known, the rubber industry has risen to the highest standards in its production in engraved and decorated rubber, some of the productions having been really above the heads of the buying public. This is also rivalled by the products of the plastic trade, which has the same limitation as the rubber industry in the provision of suitable moulds, but if beautifully finished

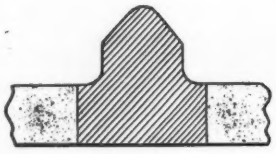


Fig. 2.—Suggested "ideal" dowel.

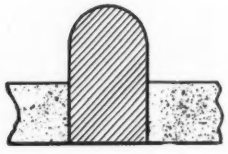


Fig. 3.—Old-type dowel.

goods could be produced from repetition formers not only would their cost to the public be reduced, but their consumption might be increased by other reasons of beauty and finish.

If any research chemist in the plastic industry desires help or information as to the conditions in which rubber-producing moulds are used, with either highly accelerated short period cures of rubber, or low temperature time cures, I shall be only too glad to give him the required technical information.

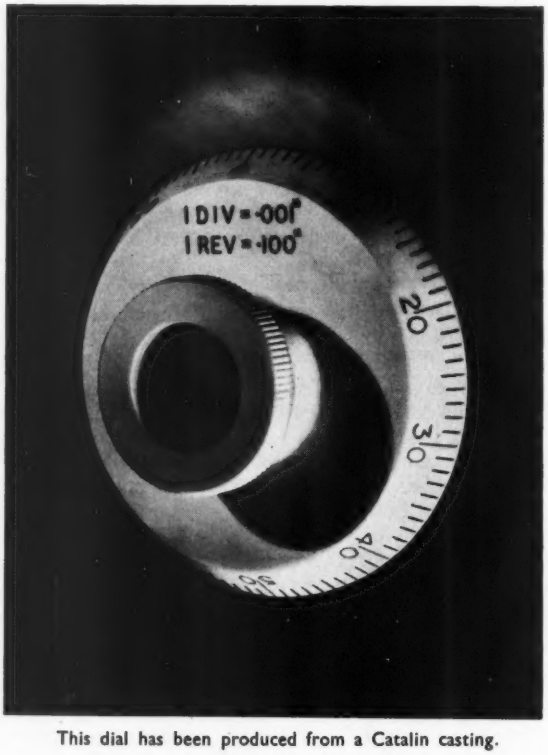
The Editor of *Plastics* has opened up most interesting possibilities in his suggestion and these notes are offered as a follow up to them and perhaps as an opening to further discussion.

CATALIN MICROMETER DIAL

Cast resin produces a fine-adjustment instrument

Mr. Marti of Catalin, Ltd., has sent us the photograph reproduced below in the hope that it will interest us. We can assure him that it does so indeed, for we are very anxious to see the utility of cast resin spread in spheres outside the purely fancy goods section of industry.

The object in question is a micrometer setting dial for use on machine tools and has been manufactured from a Catalin casting by the well-known concern Kendall and Gent, Ltd.



This dial has been produced from a Catalin casting.

Education in Plastics

Notes regarding the Curriculum of the Plastics Industries Technical Institute that has recently been opened in the United States

Our old friend Mr. E. F. Lougee, at one time Editor of *Modern Plastics* and who is now Chairman of the Board of Governors of the new Institute in Los Angeles, California, has sent us the curriculum, which we have pleasure in publishing herewith. It is worth while recording, for the information of those in this country who are interested in plastics education, the different members of the staff of the Institute. They give an indication of the thoroughness and broad outlook with which the problems of the whole realm of plastics is being attacked.

Other members of this board include Donald Dew, Diemolding Corp., Canastota, N.Y.; Dr. Gordon M. Kline, Plastics Division, National Bureau of Standards, Washington, D.C.; Spencer E. Palmer, Tennessee Eastman Corp., Kingsport, Tenn.; and Louis M. Rossi, Bakelite Corp., New York.

STAFF

John Delmonte: Graduate of the University of Pennsylvania. Joined Naval Aircraft Factory. Research work with Firestone Tire and Rubber Co. and Chicago Flexible Shaft Co.

Dr. John P. Trickey is in charge of chemical research and moulding. Pioneer in the development of furfural resins for Quaker Oats Co., and worked six years with Carbide and Carbon Chemical Corporation.

Frederic Seljé. Recently Director of Interior Art and Body Design at Chrysler Corp. Is Director of Design of the Institute.

Dr. Paul W. Ivey. Professor of Sales Research and Merchandising at University of South Carolina, is Director of Merchandising and Sales Research.

C. K. Castaing. Director of Fabrication. Four times winner of *Modern Plastics* award for design and work in the fabrication of plastics.

GENERAL SUBJECTS

Historical Background of the Plastics Industry.
Polymerization Phenomena and the Formation of Plastics.
Introduction to Organic Chemistry.
Formation of Phenolic Plastics.
Urea Resins and Their Characteristics.
Polyvinyl Resins and Their Characteristics.
Acrylic and Polystyrene Resins.
Cellulose Plastics—Origin and Chemistry.
Introduction to Cellulose Chemistry.
Utilization of Farm Products and Waste Materials in Plastics.
Miscellaneous Resins (including Natural Resins, Rubber Derivatives, Alkyds and the Polyamides).
Synthetic Rubbers and Rubber-like Materials.
Rubber Chemistry—Introduction.
Physical Properties of the Plastic Materials.
Review of Strength of Materials.
Electrical Properties of Plastic Materials.
Chemical Properties of Plastic Materials.
Optical Properties of Plastics.
Design of Moulded Plastic Parts.
Insulating Foils, Threads, and Packaging Materials.
Moulding of Plastics—Materials—General.
Moulding of Plastics—Procedure—General.
Cold Moulding and Material Properties.
Mould—Design—General.
Laminated Plastics—General.
Casting of Plastics—General.
Extruding of Plastics.
Fabrication of Plastics by Drawing, Forming and Cementing—General.
Testing Methods for Plastics—General.
Plastics as Applied to Surface Coatings.
Economics of Plastics and Their Applications—General.
Styling and Art in Plastics.

ELECTIVE SUBJECTS

Moulding.—Study of Moulding Materials and Flow Properties.
Dependence of Properties of Materials upon Methods of Moulding.
Preparation of Materials for Moulding.
Types of Compression Moulding Presses (Operations and Maintenance).
Types of Injection Moulding Presses (Operations and Maintenance).
Extrusion Presses and Their Operation.
Review of Mould Types.
Fully Automatic and Semi-automatic Moulding.
Heat and Pressure Developing Means.
Accessories for Moulding and Their Design.
Moulding Plant Layout.
Finishing Operations and Inspection.

Mould Design and Construction.—Fundamental Requirements of Thermo-setting and Thermo-plastic Composition in Moulding.
Types of Moulds (Flash and Positive).
Injection and Transfer Mould Design.
Materials Employed in Mould Construction.
Machining and Hobbing Moulds (Theory).
Special Methods for Making Moulds.
Design of Shrink Fixtures, and Tools for Finishing Plastic Materials.
Gauges for Checking Mould Construction.
Design of Extrusion Dies, Preforming Moulds, etc.

Casting.—Materials Suited for Casting Purpose.
Production Techniques Developed for Casting Phenolic Resins and Acrylic Resins.
Moulds for Cast Phenolics—Steel Mandrels and Rubber Moulds.
Preparing Composite Castings of Two or More Materials.
Properties of Cast Plastic Materials as Compared with Other Grades.
Casting of Thin Films.

Laminating.—Procedure of Impregnating Fabrics, Paper, Asbestos and Wood.
Presses and Equipment Required for Laminating Plastic Materials.
Classifications of Phenolics according to the N.E.M.A.
Lamination of Rods, Tubes and Bearings.
Physical, Electrical and Chemical Properties of Laminated Plastic Materials.
Special Machining and Finishing Requirements for Plastic Materials.
Use of Uncured Scrap from Laminated Plastics in the Manufacture of Special Gears and Pulleys.
Laminating of Wood Veneers and Papers Through the Use of Thermo-plastic Sheets and Resin Films.
Design of Moulds for Laminating.
Methods of Applying Laminated Plastics.

Fabricating—Thermo-plastic Qualities of Plastic Materials.
Selection of Materials and the Colours Available.
Moulds and Forms Useful for the Forming and Drawing of Plastic Materials.
Preparation of Various Cements and Solvents.
Methods of Assembling Plastic Materials.
Special Techniques for the Fabrication and Forming of Laminated Phenolics and Laminated Urea Plastics.
Applications and Uses of the Various Extruded Plastics.
Manufacture of Articles from Plastic Sheets and Rods.
Treatment of Cloth to Render It Waterproof.
Finishing Treatments for Thermo-plastics.
Comparative Machining Characteristics of Plastic Materials with Emphasis on Cast Phenolics.
Packaging Materials.

Testing.—Why Plastics Differ from Other Materials of Construction and Wherein Test Methods Will Differ.
A.S.T.M. Procedures and Dependence upon Humidity and Temperature.
Procedure for Creep and Cold Flow Measurements: Special Optical Tests, etc.
Special Tests by Materials Manufacturers.

Designing and Styling with Plastics.—Relationship of Art to Civilization.
Industrial Art and Design.
Plastics in Modern Design and Merchandising.
Plastics in Decoration.
Plastics in Architecture.
Plastics in Business.

Merchandising of Plastics.—Marketing of Plastics.
Marketing Finished Plastics Products.
Knowing Your Product.
Wholesale and Retail Selling.
Sales Technique.
Review and Survey of Plastics Market.

Advanced Theories of Polymerization and Formation of Plastics, available only to men with advanced chemical background.

Four general and two special courses are available at Plastics I.T.I. The first, an Engineering Course, requires one year of resident study and training in the theory and practice of plastics, covering a complete curriculum of general and elective subjects. Additional work in plastics development and research will be available to those students demonstrating outstanding ability upon completion of the one-year course.

The Resident Day Course and Resident Night Course require about three and one-half months for completion. Both cover the same general curriculum, but the night course is provided for those otherwise occupied during the day. Each of these courses includes theoretical and practical training, plus one elective subject chosen from the several branches of the plastics industry.

A specially designed course in applied plastics engineering for aircraft engineers, custom or consumer moulders and shop superintendents is conducted one evening each week.

Standard shop equipment, including an automatic moulding press, preform press, compression and injection presses, laboratory presses, fabricating machinery, laboratory and testing apparatus, has been purchased and is being installed at the Institute as rapidly as delivery can be made.

Standard Methods for Testing Rubber

In the course of the preparation of British Standards for Rubber Products it became apparent that the practical co-ordination of methods of testing would be considerably facilitated by the issue of a British Standard recommending methods of testing rubber. The tests so far standardized by the British Standards Institution have been published in two British Standards as follows:—

B.S. 902. Methods of testing latex, raw rubber and unvulcanized compounded rubber.

B.S. 903. Methods of testing vulcanized rubber.

The methods are applicable to:—

(i) Latex, in a natural or prepared form.

(ii) Raw rubber, in the crude form obtained on the coagulation of latex.

(iii) Unvulcanized compound rubber obtained from raw rubber by the incorporation of various ingredients.

(iv) Vulcanized rubber, that is to say, the product obtained from natural raw rubber by heating it with sulphur and/or sulphur-containing compounds. This latter product may be of a soft extensible character or it may be of a hard inextensible character, such as ebonite.

Copies of these British Standards may be obtained from the British Standards Institution, 28, Victoria Street, London, S.W.1.

Science in the War

It is announced that in order to ensure the continuance of the fullest co-operation of scientific workers with the Government in the national war effort, the Lord President of the Council, after discussion with the Royal Society, has, with the approval of the Prime Minister, appointed a Scientific Advisory Committee with a secretary from the Cabinet Secretaria. The members are: Lord Hankey, G.C.B., G.C.M.G., G.C.V.O., Chancellor of the Duchy of Lancaster (chairman). Sir William Bragg, O.M., K.B.E., President of the Royal Society. Dr. E. V. Appleton, F.R.S., Secretary of the Department of Scientific and Industrial Research. Sir Edward Mellanby, K.C.B., F.R.S., Secretary of the Medical Research Council. Sir Edwin Butler, C.M.G., F.R.S., Secretary of the Agricultural Research Council. Prof. A. V. Hill, O.B.E., F.R.S., M.P., Physical Secretary of the Royal Society. Prof. A. C. Egerton, F.R.S., Biological Secretary of the Royal Society. The terms of reference of the committee are:—

(a) To advise the Lord President on any scientific problem referred to them.

(b) To advise Government Departments, when so requested, on the selection of individuals for particular lines of scientific inquiry or for membership of committees on which scientists are required, and

(c) To bring to the notice of the Lord President promising new scientific or technical developments which may be of importance to the war effort.

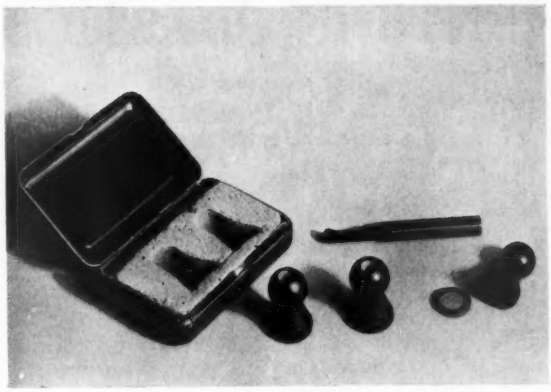
Control of Tar Products

The Minister of Mines has appointed Major T. Knowles to be Controller of Tar Products. The control is being instituted to regulate and co-ordinate production and consumption of tar products.

Major Knowles is vice-chairman of the board of Monsanto Chemicals, Ltd., and since the appointment is a full-time one his company has granted him an indefinite leave of absence.

The new Controller brings to the post an extensive background gained in chemical industry, and his experience as a director of the Creosote Producers' Association and as a member of the Council of the Association of British Chemical Manufacturers will be invaluable in the complexities of his new office.

Mr. A. D. Daysh, director of Monsanto Chemicals, Ltd., who has worked closely with Major Knowles, succeeds him as head of the sales activities of the firm.



THE DEFENCE OF THE EAR

One of the Smallest Mouldings Made as a Unit, Plays an Important Role in War as Well as in Peace

THE Government's general issue to the public of rubber plugs as ear protectors against the effect of blast has brought into prominence some of the apparatuses that have long been in existence for similar purposes, not only in war-time for the Navy and Army, but for many peaceful applications.

One of the best known is the Mallock-Armstrong Ear Defender, which was first invented a few years before the 1914-1918 war as a result of experiences on the gun-testing ranges of the famous armament works of Armstrong Whitworth. There is little need to stress the importance of ear-drum protection when big naval guns are being tested. In the ensuing years of peace the Defenders found favour in many industries from which excessive noise was inseparable, if undesirable—particularly in the rapidly growing aircraft industry where they were extensively used in the engine-test shops. The outbreak of the present war has caused the main use of the Defenders to revert once more to the Services. Industries are, however, also employing the Defenders in increasing numbers and applications.

Our interest in this small apparatus lies not only in its useful industrial application, but perhaps to a greater extent in the fact that it is manufactured from plastic material and while it cannot be said that the sale of synthetic resin is enormously increased by this little industry (we suppose 10,000 units could be made from about 25-30 lb. of moulding powder), yet the moulding job is an interesting one. Indeed, the smallness of the mouldings and of other plastic parts, all of which must be produced with fairly close limits, places the units in a class of their own.

Construction

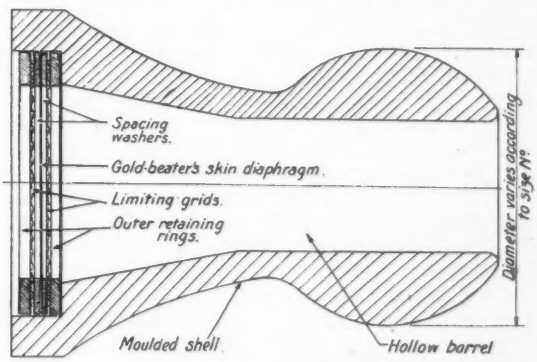
Each Ear Defender is made up in eight parts. The body or shell, which is a phenol-formaldehyde moulding in the form of a " halma man " and is hollow from end to end. The drum, which is the main protective element and comprises the remaining seven parts, is fixed into the base of the shell (the opposite end to that which fits into the ear) and is composed of a sensitive diaphragm of gold-beater's skin, held between—but out of contact with—two wire-mesh screens spaced from the diaphragm so as to limit the movement of the latter and thus prevent the transmission of very loud sounds.

The diaphragm is not stretched tightly and has a very low natural period. Retaining-rings, made of celluloid, are placed on the outer sides of the wire-screens and all parts are pressed together to form a single unit, each being carefully tested to ensure that the drum is airtight and that the diaphragm moves freely between the screens.

Each pair of Defenders is packed firmly in a sponge-rubber moulding. Also included in the outfit is a cleaning spoon for removing wax from the hollow barrel of the Defender; this is machined from casein rod and fits into a special recess in the rubber " holder." The whole outfit can thus be carried in the pocket without rattling.

Function

The bulbous end of the Defender is fitted into the outer canal of the ear which—if the Defender is a good fit—it completely fills and blocks all passage of air from entering the ear. The diaphragm, free to vibrate within the limits of the screens, faithfully passes on to the ear all sounds of normal amplitude, such as speech, music, etc., but in the presence of loud noise the diaphragm's movement is restricted and in consequence the passage of the noise is largely obstructed. Likewise, any sudden change of air-pressure such as would be caused by an explosion or series of explosions is unable



Cross-section showing fitting of diaphragm into the moulding

to reach the ear-drum, as it causes the diaphragm to lean against the screen where any further movement is checked.

It will readily be seen that the presence of the Defender in the ear obviates all likelihood of a ruptured ear-drum, and even the temporary deafness, which usually follows exposure to excessive noise, is completely eliminated and the hearing remains fully sensitive for the reception of small sounds.

(Continued on page 250.)

AIRCRAFT DEVELOPMENTS IN PLASTICS

Some Important Lines of Development with Regard to the Use of Plastics in the Airframe and the Aircraft Engine are Reviewed and Commented Upon

THE search for new materials of aircraft construction centres chiefly round the finding of materials of ultra-low specific gravity, so that the stiffness resulting from a bulky section may be utilized to prevent bending and buckling of components in service.

Broadly speaking, the chief stages through which aircraft construction has up to the present passed have been that of wood and fabric, steel tubes and fabric, and, finally, the all-light-alloy cantilever monoplane utilizing the monocoque or stressed-skin type of construction. The latter method was, of course, rendered possible only by the evolution of high-strength heat-treatable aluminium alloys which could be employed in the form of sheet and strip, although alloys of the strain-hardening class are now being exploited by certain aircraft manufacturers.

Low as the average specific gravity of aluminium alloys is compared with that of steel (approximately 2.5 as against 7.8), it is yet too high to permit of the use of sheet in any but light gauges. Consequently, the sheet skin of a monocoque structure, such as a fuselage, must be supported against buckling under compression by reinforcing stiffening members, generally comprising transverse frames connected by longitudinal stringers.

Whilst this method of construction has proved to be singularly successful, being used almost universally at the present time for all high-performance aircraft, it involves considerable manufacturing difficulties. Extruded sections of the most-complicated shapes are needed in very large numbers, whilst the forming of sheet to the required profiles necessitates specialized pressing and heat-treatment equipment. In cases where the forming is very severe, frequent re-heat treatment, which brings in its train the many metallurgical troubles which inevitably result from unduly prolonged heating, is generally necessary, the only possible alternative being the provision of highly specialized refrigeration storage equipment.

The assembly of fabricated parts necessitates the employment of huge numbers of closely spaced rivets which, if of high-strength alloy, again set up a need for refrigeration storage, whilst the need for achieving smoothness in all surfaces exposed to airflow necessitates the use both of specialized rivets and riveting equipment. Progress made in spot welding may ease the position in this respect, but it is as yet too early to attempt to forecast the extent to which aircraft constructors may be able to rely upon the process.

The Search for Low-density Materials

It is, therefore, not surprising that aircraft designers the world over are searching for low-density materials which can be used in sections thick enough to avoid the complications of reinforcing members and structures, and the forming of which is free from the problems encountered with light-alloy sheet. Reference has already been made in this journal to the potentialities of cellulose materials impregnated with phenolic resins. Research is being increasingly carried out on these materials, and the results already achieved show considerable promise. It will, however, be of interest to examine the work carried out in certain other directions.

Moulded vulcanite impregnated with nitrogen bubbles has been suggested, the impregnation being carried out on the heated vulcanite in a manner suggested as being analogous to the working of yeast in bread dough. It is possible with this material to achieve a specific gravity as low as 0.1, whilst, due to its true cellular structure, the moisture absorption also is extremely low. For example, a piece of the material soaked in water for considerably over 200 hours absorbed only some 0.6 per cent. by weight. It is easily worked and moulded into any required shape, but as yet the desired combination of strength, elasticity and durability necessary in a major aircraft material has not been achieved. The use of the product in present-day aircraft is confined chiefly to seating and flooring, uses for which its exceptionally high degree of flame resistance renders it especially suitable.

The Lessons of Wood Structures

The experience gained in wooden construction during the early days of flying provided a useful basis from which several investigations into the use of plastics have been initiated. The multitudinous troubles experienced with aircraft employing wood in the simple or laminated form are well known and need not be recapitulated here. They were, however, such as to demonstrate the unsuitability of the medium, particularly where varying climatic and " weathering " conditions are encountered.

Nevertheless, it must be remembered that a good-grade straight-grained wood possesses, as a natural result of its fine cellular structure, the important property of low specific gravity. Thus the specific strength figure is high whilst the excellent elastic properties possessed by good grades of constructional timber enable them to be stressed almost to breaking point without acquiring permanent deformation. The preservation of these natural properties without undue increase in density has been the subject of considerable investigations.

Improving on Wood

The most difficult problem has been, of course, to reduce moisture penetration and absorption to a minimum. Satisfactory methods of doing this have existed for some time, but they involved too great a density increase to enable the product to be used in sections thick enough to avoid the need for reinforcing members with its attendant complication in manufacture.

As a result of work by the Bakelite and Haskelite Corporations, however, this problem has been largely overcome. The resulting products possess a good resistance to attack by moulds and fungi, whilst a further problem commonly encountered in using wood—the difficulty of carrying out adequate inspection—is overcome by the fact that the wood is used in the thin veneer form. A product of this type is Duramold, used by the Clark Aircraft Corporation in the U.S.A., to which reference has been made in past issues of this journal.

In a paper read before the World Automotive Engineering Congress of the Society of Automotive Engineers in 1939, V. E. Clark, of the Clark Aircraft Corporation, gave some interesting particulars regarding the product, although, unfortunately, he stated that fundamental details regarding the basic materials and their processing could not as yet be divulged.

Bakelite in various forms is used, the process of building up the product and moulding it involving careful manipulation of temperatures and pressures, especially with regard to time. The material is stated to be highly resistant to temperature changes. Part soaked in water for two hours at 140 degrees F. and then exposed to a temperature of 70 degrees F., showed no deterioration, even after numerous repetitions of the cycle of operations.

Moulded Shapes and Physical Tests

A complete half shell, it is claimed, can be formed with either simple or compound curvature, practically no change in moisture content occurring during the moulding operations. The material is hightly resistant to flame, and the high surface finish possible indicates that much less power would be required for an aircraft having its fuselage and aerofoil surfaces than for the all-metal aircraft in which riveting is employed. Clark gives the reduction as being of the order of 25 per cent. The high heat insulating properties of the materials should, of course, be efficient in preventing icing.

The specific gravity may be controlled within ± 3 per cent. of any required value between 0.5 and 0.9, the strength and modulus of elasticity in this range varying approximately as the density. Examples of the mechanical properties achieved with various types of Duramold are given in an accompanying table taken from Clark's paper.

Table 1.

Values given are in lb. per sq. in. divided by 1,000 × S.G. of material.

Type of Duramold	Direction of applied load	Tension	Compression	Young's modulus T and C
I	Optimum	25.75	13.95	3,060
	90 degrees to optimum	4.72	7.70	714
II	Optimum	22.73	13.03	2,730
	90 degrees to optimum	7.75	8.60	1,053
III	Optimum	19.69	12.08	2,380
	90 degrees to optimum	10.80	9.51	1,395
IV	Optimum	16.75	11.22	2,040
	90 degrees to optimum	13.87	10.40	1,732

Resistance to fatigue—based on allowable stress—(for equal weight per unit area) is claimed to be 50 per cent. higher upon that of a heat-treatable aluminium alloy of the duralumin type, whilst the absence of hysteresis within the limit of proportionality which, in tension, is practically the same as the ultimate strength, ensures that there is no creep. The specific strength figure of the Type I material is, it will be noted, approximately the same as that of a 90-ton steel.

Importance of Compression Strength

It is the strength of the material in compression, however, which is of particular interest to the aircraft constructor. Calculation by the chief engineer of Clark Corporation on the strengths of cylinders under axial compression loads furnish valuable information in this respect. In all cases the cylinder diameter is assumed to be 60 ins., the weight per foot constant, and the spacing between transverse rings 30 ins., the basis for comparison being a smooth-skin aluminium alloy (17ST) cylinder with skin .032 in. thick, reinforced by flanged Z stringers $\frac{7}{8}$ in. by $\frac{1}{2}$ in. by 1-20 in., with 6-in. spacing, the total stiffening area being 3.28 sq. ins.

Such a reinforced cylinder is calculated to support a load of 63,000 lb. An unstiffened cylinder of the same material would support 30,000 lb., whilst a cylinder of reinforced synthetic resin (say, phenol-formaldehyde reinforced with fabric or cord), would support about 8,000 lb. Constructed in Duramold Types II and III, however, the cylinder would support some 113,000 lb., i.e., 80 per cent. more than the reinforced duralumin cylinder and 14 times as much as the plastic cylinder.

The Clark Structure

The material has already been used successfully in the construction of the fuselage of the Clark five-seater aircraft. It is proposed to extend its application to other parts of the structure in which a multiplicity of riveted reinforcements are generally required, notably the wings and the tail unit. The material is, of course, not suitable for components of the landing gear, etc., nor is it proposed to use it at present for parts such as elevators, rudders, ailerons, cowling and fairing pieces. Such parts may be readily pressed out in aluminium alloy and do not add to complexity of manufacture. In view of the interest which the work in the Clark aircraft has aroused in the past, the new developments will, no doubt, be watched closely by aircraft designers and constructors.

Rubber and Synthetics

With regard to the aircraft engine, the chief developments have been in the direction of providing synthetic rubbers suitable for engine mounting. Unfortunately, much of this development work is being kept a close secret at the present time, but it will be of interest to indicate the lines along which the German synthetic rubber industry was attempting to solve the problem immediately prior to the war.

The Buna material, upon which German chemists have specialized, and to which some attention will be given in our pages in the future, was primarily chosen for tests in marine and automobile engines, the mounting elements being arranged so that the engine speeds were either above or below the critical speed. Steinborn, writing in *Jahrbuch, 1938, der Deutsche Luftfahrt Fooschung*, admits that from the outset considerable difficulties were encountered.

Attempts were made to find original solutions to the problems presented by aircraft engines, since the research workers were confronted with some confusion as to whether the designer of the airframe or the designer of the engine was responsible for the elastic mounting. It was found, however, that theoretically evolved designs were useless for practical purposes. Mounting blocks for engines below the critical speeds proved to be much too big, Steinborn quoting a size of mounting 100 by 80 by 150 mm. in compression.

For engines running above the critical speed, the damping elements were necessarily restricted to a small rubber volume in order to provide a sufficiently high frequency in all six degrees of freedom. This restriction made it impossible to assume that the elements would function elastically under all conditions of service. It was also found impossible to evolve theoretically designs in which self-frequency figures existed between defined limits for a given speed range, since the primary causes of vibration and the speed ranges in which resonance occurred were not known to the research workers.

Difficulties in Engine Mountings

It was therefore decided, what should, of course, have been realized from the outset, that the only practicable approach to the problem was for the engine designer to indicate at the appropriate stages during the evolution of the design, information sufficient to enable installation sketches and load-travel curves to be drawn, also force distribution diagrams for each point of the mounting.

The realization of the need for what must be a somewhat lengthy approach to the use of Buna for aero engine mountings undoubtedly proved disconcerting to those who were attempting to force the adoption of the material for reasons of political economy. In contradistinction to other German writers on Buna, who pause at appropriate moments to pay somewhat unconvincing tribute to the existing German regime in making the country self-sufficient in essential materials, Steinborn points out that the progress in introducing a new material can be made only as a result of exhaustive analysis and testing at every step. As a safety precaution, no doubt, he points out that such is the only way to inspire confidence in a new material and that it will undoubtedly be best in the long run for the widespread development of Buna.

Strength figures quoted for rubber components as a guide for aircraft engine designers are:—For rubber loaded in compression, 142-214 lb./sq. in. in normal cases, with maximum figures of 570-710 lb./sq. in. where the deformation is limited by stops; under shear load the normal figure is 43-71 lb./sq. in. and the maximum figure 214 lb./sq. in. It is recommended, however, that all strength figures should be given in terms of a standard test block.

American practice with regard to hardness measurements is to use the well-known Shore method; but in Germany the D U M hardness method has been introduced. In this test the ball diameter is 10 mm., the initial load 50 grm., and the additional test load 1 kgrm., the testing time 10 secs., and the rubber thickness 6 mm. The impressed depth is measured and given as a hardness value in 1/10 mm.

Damping by Buna Rubber

Damping qualities of Buna are claimed to be higher than those of natural rubber, as a result of hysteresis tests carried out by I. G. Farbenindustrie and Continental Cabutchoue; no quantitative results, however, appear to have been published. Damping of rubber decreases at higher temperatures, whilst at temperatures of the order of 50 degrees C. a somewhat serious stiffening is experienced. Elasticity changes which occur in rubber may, in the most unfavourable circumstances, range up to 50 per cent. Buna is stated to show an improvement over natural rubber with regard to behaviour under varying temperatures.

Bonding with steel discs is preferred, although light alloys such as duralumin and silumin, or Elektron magnesium alloys may be used. The ability to galvanize light alloys subsequent to the Eloxal treatment is, of course, important with regard to the use of light alloys in metal bonding. Even where such materials are used as the main mounting parts, however, it is recommended that the blocks be bonded to thin steel plates.

Design factors are primarily concerned with strength and damping figures, and the relevant data must be applied in conjunction with the engine designer in the manner indicated previously. It is also important that sharp corners be avoided at metal parts and all corners be chamfered. Bonding plates should be capable of easy adjustment and interchangeability, and care be taken that stresses are distributed uniformly throughout the rubber material.

THE DEFENCE OF THE EAR

(Continued from page 247)

In order to ensure accurate fitting, the Defenders are made in several sizes (ranging from .32 in. to .46 in.—maximum bulb diameter), for, in spite of many claims to the contrary, it is impossible to fit correctly ears of all shapes and sizes with a plug of only one size. One might as well expect to fit everyone with a universal set of false-teeth!

General

Readers may recall an article which appeared in the September issue of *Plastics* on the subject of ear plugs, in which investigations conducted by the Industrial Health Research Board were referred to.

It was actually the Mallock-Armstrong Ear Defenders that were used throughout these investigations, and the reason for their selection appears in the Board's Report, which says:—

> "The Defenders, if properly fitted, are quite comfortable in use and, after wearing them for a short time, one forgets their presence in the ears.
>
> "Other means of reducing noise were tried before the commencement of the investigation . . . but it was decided the Defenders described would be most satisfactory since they have the advantage of preserving small sounds so that it is possible to carry on conversation without removing them."

It is this quality of the Defenders that has made them so invaluable with the Services and industries and which lifts them out of the class of the ordinary ear-plug, for it will at once be realized that for the man whose duties continuously take him into the vicinity of really loud noise it is a boon to be able to wear continually the Defenders without the inconvenience of artificial deafness which is the inevitable accompaniment to the wearing of the usual ear-stops and, apart from subjective impressions, the Board's investigations have proved that personal efficiency does suffer to a considerable extent in workers unprotected against noise, to the consequent detriment of output.

The Value of Plastics in the Construction

The whole job, as indicated, with the exception of the diaphragm and the wire screens, is entirely of plastic materials of three different types: synthetic resin, celluloid and casein, and for the purpose it would appear that no other materials would prove as suitable. First, it is essential that the ear-protectors be light and each is about 1 grm., namely 1/28 oz. in weight. Thus, the presence of the apparatus remains almost unnoticed from the point of view of weight. Secondly, the moulding is one of close accuracy and could be surpassed only by metal which, in turn, would be unsuitable from the weight point of view. Thirdly, the material possesses that warm feeling which metal could not give. Finally, it is non-corroding, with a pleasing polished surface, and could presumably be made, if required, in transparent or flesh-coloured material. Thus the apparatus would be almost invisible.

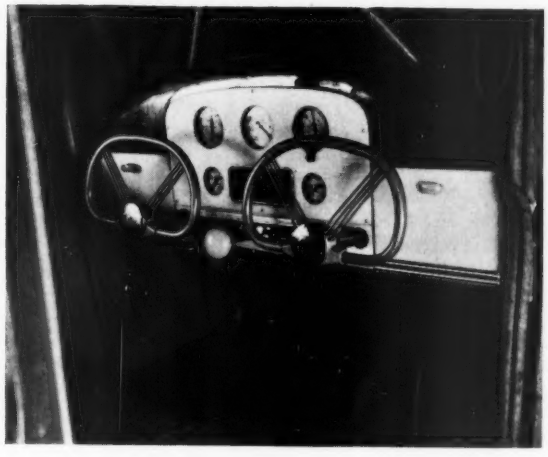
Ideas—

By the EDITOR

Polystyrene Panels

We have always regarded Germany as the home of polystyrene for a very wide range of objects, including those which are merely decorative and for which almost all other countries use a cheaper plastic. That the material has special advantages and properties is illustrated in the rather rare application shown below.

With instrument panel moulded of Monsanto polystyrene, the Aeronca Super Chief is the latest design for



private flying. These machines are used in regions varying in temperature from 120 degrees down to 30 or 40 below zero with wide variations in humidity. The plastic must withstand these extreme conditions without distortion or warpage, a requirement to which polystyrene is well adapted.

In addition, polystyrene has very low specific gravity, important in 'plane engineering, and has high impact strength. The rich cream colour of the plastic fits appropriately into the modern styling of the luxurious cabin.

The panel, believed to be the largest injection moulding of polystyrene, is produced for Aeronautical Corporation of America, builder of the Aeronca, by the Metal Speciality Co. and Thermo-plastics Incorporated.

Egg Preserving

A friend of mine, quite in serious mood, asks me why somebody doesn't put an egg preservative on the market which can be used by coating the shell with an impervious film of plastic material. He thinks the water glass process a messy one and the necessity of a barrel to contain it a serious drawback to the average householder. Certainly the latter point is most important, since barrels are worth their weight in gold to the average works and are almost unobtainable. Presumably, film-coated eggs could be stored in the usual cardboard egg boxes or, indeed, in any sort of box.

However, although no expert on egg preserving, I believe there is already a liquid on the market for the job, which is used in the way desired. But I do not know its composition and it may be a simple quick-drying varnish. On the other hand, its composition is important, for the eggs must not be tainted by strongly smelling solvent. Perhaps the best would be the emulsion type made from one of the polymers, such as polystyrene, acrylic resin, vinyl acetate or chloride. These would probably be as good as most substances from the permeability to air point of view. They could, of course, make reasonably flexible films if properly compounded. In making these suggestions one is generally confounded by the present lack of most of these materials for general consumption.

Horticultural Note

Almost as strange is the request from a reader for a plastic to serve as a sticky trap for insects; in other words, to replace and improve upon the bands tied round trees to prevent insects climbing up the trunks, hibernating in the winter and living on the fruit it takes us so much time to grow. The drawback to existing materials is that they all begin by being very sticky, but nearly always harden up, and that paper or cloth bands, being tightly drawn, do not prevent insects crawling between the bark cracks underneath the band. In fact, what is wanted is a very sticky non-hardening material that can be painted on to the tree bark and yet not harm the tree.

I do not know how these sticky substances are made, but presume they are of the lubricating-grease type or thick non-oxidizable oil or thickened oxidizable oils treated with anti-oxidants to prevent further oxidation; even thick sugar syrups, in which crystallization is prevented as far as possible, are sometimes used.

I suppose nobody has troubled to find out what stickiness means in scientific terms, and some simple data about sticky materials should be collected.

I do not see how plastics can help, especially as the industry is presumed to deal with rigid bodies, but no doubt if there is money in it there is no reason why such materials should not be made. With the present price of plastics and the low price of the normal materials used, I should say there is no hope whatsoever.

The type of plastic would probably be a partially polymerized substance, for it is well known that "degenerated" rubber and poly-isobutylene are extremely sticky. Furthermore, the partial polymerization would have to be so controlled that it continued no further and did not harden up. We should say that, just as it is difficult to prevent the hardening of drying and semi-drying oils, the problem is at present insoluble.

Some resin-like organic soaps, such as lead-naphthenate, are extremely sticky and do not harden up, especially if mixed with a non-oxidizing oil, such as a paraffinic lubricating oil. In such a condition they could be painted on the bark if warmed slightly. Because of their insolubility in water the tree should remain unharmed.

PRODUCTION

Practical Information dealing with Raw Materials, Moulding and Forming of all types of Plastics—Thermo-Hardening and Thermo-Plastic—Works-Organization, New Plant and Control Apparatus

NOTES AND COMMENTS

Plastics Control

THE following is a report of a meeting held under the auspices of the British Plastics Federation at the Holborn Restaurant, London, W.C.1, on Tuesday, October 15, 1940, at 2.30 p.m., to which all the bona-fide moulders in the country were invited for the purpose of receiving an address from the Plastics Industry Controller, Major A. Vyvyan Board, D.S.O., M.C., on the aims, objects and activities of the Plastics Control. Other officers of the Control present at the meeting were Mr. L. P. B. Merriam (Deputy Controller), Mr. H. N. Butler, Mr. P. A. Delafield and Mr. C. H. Glassey.

Mr. A. Illing, chairman of the Moulders' Section of the Federation, presided and opened proceedings by extending a very cordial welcome to Major Board and his officers.

Major A. Vyvyan Board said: "I should first of all like to explain that I myself dislike the word 'Control' because I think it sometimes conveys a meaning which is not exactly what it ought to convey. 'Control' seems to suggest an overruling authority which makes you do something you don't want to do. I am not truly a Government servant, but a man who has been chosen to do a certain piece of work during the War. The only reason I have been made Plastics Controller is because I have had 14 months' experience of other Controls and have, presumably, run them reasonably well. I cannot conceive of any other reason, and I want you to look upon me as one of yourselves appointed to co-ordinate the national need and necessity to win this War.

"I am now living in the atmosphere of the Government and my job is to see, first of all, that the raw materials we have available find their destination where they can best serve the national effort. The reason we have to approach the moulders is because the only way in which we can control raw materials is by guiding the destination of the finished goods.

"Methanol, from which, of course, we get formaldehyde, phenol and urea, are our principal raw materials, and we have to conserve. We have to find out exactly what they are being used for, whether they go to meet direct Service needs, whether they go to supply indirect demands for the Air Force, Army or Navy, whether they are essential in the export market to earn dollars, or whether they are essential for home sale. In order to perform that function I can tell you that it is absolutely vital that we should have the full and willing co-operation of you gentlemen here. We are a democracy with the job of winning the War. How are we going to help win the War? By seeing that all our products are used in the national effort.

"We have to issue a lot of forms which you may consider vexatious, but the only reason for employing them is so that we can obtain the information you want us to have. It is merely to help us in guiding the destination of the raw materials we have, and we must know how much of these goods are essential for war purposes. We must know and unless you give us this information we shall go astray.

"The raw materials which we have available to-day are not in abundance, for, as you know, certain raw materials are made in only a limited number of factories. I must ascertain the normal amount of raw materials necessary to keep the plastics industry going. I have to guide the industry, but how can I do it without knowing the destination of the raw materials? I put it to you in this way. Those forms, on which you are asked to tell us exactly what percentage of your output goes for Government purposes, must be filled up accurately or we may go fundamentally wrong. Those forms will guide us as to whether we should provide additional manufacturing capacity in this country or whether we have to use dollars in order to purchase from overseas what is fundamental for Government needs. Everyone who completes these forms should realize that he is giving essential information, and I do hope to have your whole-hearted co-operation."

Mr. L. P. B. Merriam explained that, on and after November 1, 1940, no moulding powders, whether in stock or on order, could be used except under the authority of a licence granted by the Plastics Control. The only exception was that any moulder might use and/or acquire without licence a total of not more than 2 cwt. of all types of moulding powder in any one month.

Mr. Merriam then went on to describe in detail how the questions on the forms should be answered and said that he was sending to each moulder full explanatory notes. He added that the Control appreciated the importance of certain civilian needs. If rationing had to be introduced it would be the duty of the Control to carry this out.

A number of questions arising from the explanation of the machinery of the Control were then asked and various points elaborated. All these matters were dealt with by the Controller and his officers.

Notice

We are doing all we possibly can to ensure that *Plastics* reaches you regularly every month, but occasionally there may be a delay owing to the dislocation of transport by air raids. If, therefore, *Plastics* should arrive after the normal day of sale, please help your newsagent by accepting your copy as usual. Under the Government's Paper Control Order he is unable to return unsold copies, and if you refuse to accept your own copy he will have to pay for it himself. Your newsagent is working under most difficult conditions and your kind co-operation in this matter will be greatly appreciated by him and by ourselves.

FILLERS IN PLASTICS

Their Relationship in Theory and Practice

By P. GRODZINSKI

IN the plastics industry, the filler is mainly considered as a component added to increase the bulk of the mass and thus reduce the price of the final product. The problem is sometimes tackled from the point of view of the amount of filler which can be added to the mix without unduly impairing its mechanical, physical and electrical properties. This latter standpoint is frequently adopted by the selling agent who, naturally, may wish to offer the cheapest product, but it is to be questioned, as it bears, in itself, a number of dangers which may readily be avoided by a better analysis of the main principles.

In practice, working to the lowest limits of resin content has always proved to be a mistake. If it were possible, in every instance, to determine all mechanical, thermal, electrical and other properties of the product, and to find out which filler content gave the most satisfactory product with respect to cost of filler and resin, applied pressure, moulding time, etc., it might, indeed, be possible to operate according to this principle of maximum filler and minimum resin contents. There must, however, always be left a safety margin as, sometimes, none of the desired properties can be determined on the finished work. Very often it is not known with any degree of accuracy to what stresses and strains the component will be exposed in practice.

The attitude referred to above is, therefore, not tenable even from a technical and commercial point of view; it is far more liable to criticism from a scientific viewpoint. The filler must not be considered as being merely mechanically admixed with the resin. This might be partially true where no appreciable physical interaction can be expected to take place between resin and filler, such as in the case of quartz or stone flours. Even with asbestos fibre, the loose mass can be filled by the resin, and thus strengthened or reinforced, and in the case of cellulose and wood flour fillers, a type of chemical reaction must be assumed, otherwise it is difficult to explain how the tensile strength of laminated paper can be increased to about 16-fold the tensile strength of the untreated paper.

Reaction between filler and resin will, of course, tend to be conditioned by moulding temperature and moulding time. In the case of soya-bean fillers, it appears that a chemical reaction, which influences physical properties, takes place between the components. Such investigations are still lacking with regard to cellulose and wood-flour fillers.

In the case of rubber, the process of interaction between filler and base has been made clear by Wiegand, and similar conditions may prevail for plastics. In the rubber industry, certain reinforcing ingredients produce properties which are better than those exhibited by the base material. Such active fillers are lamp black, zinc oxide, magnesium carbonate and kaolin. With increasing fineness, the action of these ingredients increases.

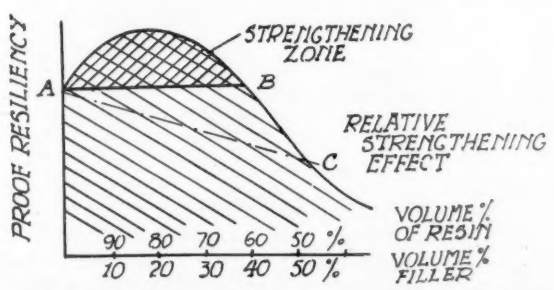


Fig. 1.—Reinforcing action of fillers. (W. B. Wiegand.)

Wiegand demonstrated that close connection exists between surface activity in the filler and its reinforcing action. If proof resilience (used by Wiegand as a measure for the reinforcing effect) be plotted against volume per cent. of filler (Fig. 1), the curve showing the degree of activation rises until the filler content exceeds a certain level. The inclined straight line AC (Fig. 1) shows the proof resilience of the available amount of base mixture; a reduction in the physical and mechanical properties of the final product takes place at a very much higher percentage of filler.

Basic Mathematical Relations

The composition of a mix is usually expressed in weight per cent. For instance, 40 per cent. resin and 60 per cent. wood flour. This is the most simple method from the production standpoint, but the final chemo-physical conditions attained can properly be considered only from the point of view of volume (Fig. 1). If the specific gravities of the two components be the same, no difference exists between the two methods.

To change from one system to the other, the following relations, due to Hartner, may be used:—

f = Volume per cent. of filler in a mixture.

F = Weight per cent. of filler in a mixture.

$$k = \frac{s_f}{s_r} = \frac{\text{S.G. of filler}}{\text{S.G. of resin}}$$

$$f = \frac{100 \times F}{100 \cdot k - F(k - 1)}$$

$$F = \frac{100 \times k}{\frac{100}{f} + (k - 1)}$$

The volume, v_m of 100 parts by weight of a mixture, is then

$$V_m = \frac{F}{s_f} + \frac{100 - F}{s_r} \quad \text{and} \quad f = \frac{v_f \times 100}{v_m}$$

To illustrate the application of these formulæ, assume a mixture of 50 per cent. phenol resin and 50 per cent. filler. What are the volumes per cent. of filler when (a) wood flour (S.G.0.45), and (b) asbestos fibre (S.G. 2.2) are used; the S.G. of the phenol resin is assumed to be 1.07. For a, k=0.4; for b, k=2.0. We obtain for a, f=71 per cent. and for b, f=33 per cent., i.e., for wood flour the mixture contains more than the double bulk of filler than when asbestos fibre is used. This means that the asbestos fibre can be far better covered, or impregnated, with resin. A more thorough investigation of these and cognate problems would be of great value.

A further interesting fact is that relatively slight variations in the resin/filler ratio of a mixture have considerable effects on the mass and volume distribution in the material itself. If, for instance, a mixture of 50 per cent. by weight of resin and 50 per cent. by

weight of filler be reduced to a mixture of 40 per cent. resin and 60 per cent. filler, then, whereas in the first case one part by weight of resin can engage one part by weight of filler, in the second case one part resin must engage 1.5 parts of filler. Thus, a variation of 50 per cent. has been effected in one characteristic.

Structure and Grain Size of Filler

In a ground and screened mass of fillers, various sizes and shapes of grain are present; the sifting process tends only to exclude particles larger than those corresponding to the mesh of the screen. According to Rowell, no two batches show the same proportion of fine, medium and coarse particles. Fine particles are, as a rule, less than one-tenth the size of the coarse.

Rowell ("Technology of Plastics") states: 1 lb. of large particles of 200-mesh mineral flour (maximum grain size, 0.002 in. side length) have a surface area of about 20,000 sq. ins.; 1 lb. of fine particles have a surface of about 200,000 sq. ins. One lb. of binder would, if evenly spread, cover about 25,000 sq. ins. to a thickness of 0.001 in. The average surface area of 1 lb. mixed-size filler is 100,000 sq. ins.

In the case of 2½ lb. filler to 1 lb. binder (or approximately equal volumes of filler and binder), the thickness of the coat of binder when evenly spread is 0.0001 in., but, in practice, the mass is never evenly spread, and the particles are neither all covered, nor all separated one from the other. More binder is required to provide the same amount of "lubrication" to a fine filler than to a coarse.

Shape of Filler Particles

Whereas mineral particles, with the exception of asbestos fibre, may be assumed to present smooth spherical surfaces to the resin in its fluid state, organic fillers, such as wood flour and textile fibres, consist of rectangular particles.

According to Rowell, mineral particles give, in the resin-covered state, a minimum friction, as they may be considered to roll one on the other, and their total area of contact is very small. The long rectangular particles, present in the case of cellulose or wood flour, retain, when pressed together, comparatively large areas of a thin coating of binder, and eventually interlock to form a virtually immovable mass.

The advantage of these latter fillers lies in the fact that they produce agglomerates which are stronger and less brittle than those containing mineral-powder fillers. The moulding properties of short-fibred masses are, in particular, good; difficulties arise only if the fibres exceed a critical length; long fibrous fillers, on the other hand, increase the impact bending strength.

Mineral fillers, in powder form, are of small grain size and are incompressible. Wood fillers are of comparatively large grain size, and the fibres can become soaked by the fluid resin and further compressed, or bent, in the moulding process. Owing to their low specific gravity, however, the possibility exists of their segregating during the moulding process. Notwithstanding the larger surface exposed to the resin, and the higher friction encountered, better flow can be foreseen with wood-flour-filled compositions than with mineral-filled materials during moulding.

Influence of Filler-particle Size and Shape

In the case of rubber, it is well known that the grain size of the filler has considerable influence on its ability to improve the mechanical properties of the final product. For several years the German rubber industry tried to replace the American carbon black, but it was not, at first, possible to obtain substitutes with the requisite degree of fineness.

It may be said that particle size, in itself, is not the decisive factor, but that specific surface conditions must be present. In the case of rubber, the strength and toughness increase with increasing fineness of the filler.

Rupprecht has shown that similar relations exist for plastics, i.e., that some physical properties increase with reduced particle size, as shown in Table 1. Grain size

Table 1.—Influence of the grain size on the mechanical, and electrical properties of a test piece of 50% phenol with wood flour filler (according to H. Rupprecht).

Grain size No.	Impact bending strength cm. kg./sq. cm.	Bending strength kg./sq. cm.	Notch impact strength cm. kg./sq. cm.	Surface resistivity
1	6.8	770	1.6	3
2	9.3	923	1.7	3
3	6.8	793	1.5	3
4	7.0	803	1.6	3
5	5.7	640	1.5	3

No. 1 (usually classed as No. 8) is the usual commercial grade with 2 mm. maximum grain; grain size No. 2 was obtained by sifting through a screen giving 0.25 mm. maximum grain size (usual designation No. 60); No. 3 was obtained with 0.102 mm. maximum grain size (about No. 150); No. 4 was the residue of No. 3, which passed the same sieve, and No. 5 the dusty remainder from the former process.

As the table shows, the negative influence of the smaller grain sizes on the impact bending and normal bending strength is considerable, whereas the notch impact strength as well as the thermal and electrical properties do not seem to be affected. These tests confirm the usual assumption that long (and matted) fibres increase impact bending strength, but it must be observed that they somewhat hinder the moulding process. These masses with the highest impact bending strength, which contain textile fillers, give rise, it is known, to difficulties in moulding. Recently, it has become possible to preform such agglomerates, thus allowing easier and more uniform filling of the mould, but considerable increase in mould stressing is still experienced.

There is another, more practical aspect of the grain size of the filler. Dark-coloured mixes allow the use of coarser particles. The lighter the colour of the moulding powder, the finer the filler grain size must be, otherwise only a mottled effect is obtained. If a speckled mass be desired, the fineness of filler should not be carried too far, or this special effect will be lost and a uniform appearance obtained in its stead.

Owing to vibration during transport, separation of the different grain sizes in a moulding powder sometimes takes place; the large particles remain on the top, the finer particles accumulate at the bottom of the barrel. This process cannot be prevented, and it is, therefore, recommended that uniform distribution be restored by a mechanical mixing operation before moulding. The separation will be more marked in cases where great differences exist in the specific gravities of filler and binder.

Influence of the Type of Resin

In the case of one group of thermo-setting plastics, the probable competition between phenol- and cresol-resins is obvious. We will not consider this problem

Table 2.—Pressing time and degree of flow of various plastics.

Resin contents approx. %	Resin	Moulding Time seconds	Degree of flow mm.
40	Cresol	35	154
	Cresol + phenol	27	176
	Phenol	10	188
45	Cresol + phenol	16	180
	Cresol	17	196
50	Cresol + phenol	24	188
	Phenol W	14	168
	Phenol X	19	193
	Phenol Y	8	148
	Phenol Z	11	156

from the point of view of costs, but merely from the technical side. Table 3 (after Krahl) reveals relatively great differences, with respect to the degrees of flow and the necessary moulding times, between masses based on phenol and cresol.

Whereas for 40 per cent. resin contents, phenol obviously gives reduced moulding times and a higher degree of flow, the conditions in the case of 45 per cent. resin contents remain practically the same. Further large differences between commercial masses with 50 per cent. phenol contents are given in the last lines of the table, which shows that no general conclusions can be drawn with safety.

Krahl states that no exact relationship appears to exist between pressing time and degree of flow, as is shown by Table 3, in which mass A represents a 40-per-cent. resin mix with wood-flour filler having a longer

Table 3.—Length of flow bars after a moulding time of seconds (according to Krahl).

—	5	10	15	20	25	30	35
Material A ..	27	45	65	125	157	172	172
Material B ..	25	42	100	125	125	—	—

moulding time and a medium degree of flow, whereas mass B, having the same composition, shows a shorter moulding time and a lesser degree of flow. In both cases the moulding pressure was acting during the same time. This demonstrates clearly the well-known fact that degree of flow and moulding time may be influenced to a great extent by the selection of a suitable mixture with, or without, changing the ratio between resin and filler.

Influence of Resin Content on Physical and Mechanical Properties

If it be assumed that the considerations leading to the scheme in Fig. 1 are correct (and this may be so in the majority of cases), then, for all mixes, there will exist a lower and upper limit for the resin contents. The lower limit will, for instance, be determined by the fact that the mass easily disintegrates, or is too brittle, or has internal strains such as those exhibited by some of the pure cast resins on phenol and cresol bases. On the other hand, masses with reinforcing fillers such as textile fibres, and laminated plastics, should not have too high a resin content as the physical properties, such as impact bending strength, will be reduced.

Instead of reducing the resin content, the same result can eventually be obtained by reducing the amount of strengthening filler. In this regard, Brandenburger notes that a mixture of 50 per cent. resin, 25 per cent. wood flour and 25 per cent. textile fibre would give

Table 4.—Influence of resin-content and cross-section of the test bar on the impact bending strength (according to Rupprecht).

Resin contents %	Filler	Thickness of test bar mm.	Impact bending strength cm. kg./cm.²
50% Phenol	wood flour	10	8.9
		5	5.8
		3	5.1
40% Phenol	wood flour	10	8.2
		5	6.7
		3	6.6
30% Phenol	granular, inorganic mass, for instance rock flour	10	5.2
		5	3.5
		3	2.6
	fibrous, inorganic mass, for instance asbestos fibres	10	5.2
		5	4.4
		3	4.4
45% Cresol	wood flour	10	7.8
		5	6.0
		3	6.3
50% Cresol	wood flour	10	6.0
		5	5.2
		3	5.2
Urea resin	wood flour	10	7
		5	5.9
		3	5.1

results equal to a mixture of 50 per cent. resin and 50 per cent. textile fibre, which is difficult to handle.

Fig. 2, extracted from Table 4, shows, in the case of a wood-flour-filled plastic, the interesting fact that, for given cross-sectional areas, masses with lower resin contents exhibit better impact bending strength. For a bar thickness of 10 mm., the 50 per cent. phenol resin is, without doubt, superior, but, for thinner bars,

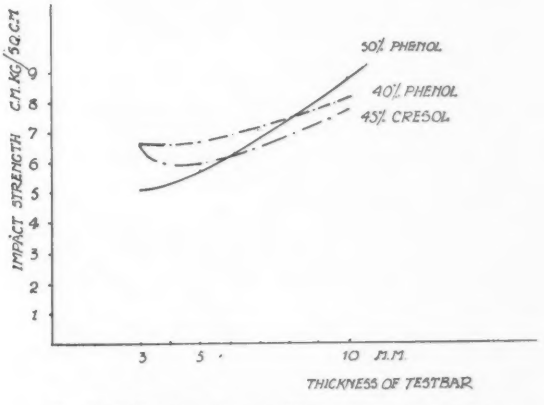


Fig. 2.—Influence of resin filler on impact bending strength of test bars.

better properties can be expected from a 40-per-cent. phenol resin, and nearly the same values are obtainable by a 45-per-cent. cresol resin; the last shows a distinct minimum for a medium bar thickness of 5 mm.

The values given in the table lead to the general conclusion that impact bending strength is reduced with smaller cross-sections. However, these results obtained for test bars are not absolutely comparable with practice, as same moulding conditions had to be kept constant for all sections, this apparently resulting in a too long moulding period for the thinner rods.

Kuntze and Nitsche recently carried out a thorough investigation on the impact bending strength of plastics of various compositions. Specific impact strength was determined for different impact speeds. This method revealed large differences in a single material group. The general conclusions drawn confirm that the urea resins with cellulose fillers, and the phenol resins with

Table 5.—Tensile strength of resin bearers and laminated plastics produced (according to W. Kuech).

Resin Bearer		Laminated Plastic			
Material	Thickness mm.	Tensile strength S		Resin Content %	S_t/S_u*
		Untreated	Treated		
Beechwood veneer	0.25	1010	2950	33	2.9
	1.2	938	3010	—	3.2
Cellulose sheets	0.15	404	1700	28	4.2
	0.15	655	2020	35	3.1
	0.55	130	2100	28	16.1
	0.55	144	—	33	—
	0.65	210	1255	12	6
	1.2	194	1400	46	7.2
Woven linen sheets	—	859	887	48	1.0
Woven cotton wool sheets	—	465	1510	83	3.2

* Ratio of tensile strength of the treated to that of the untreated material.

or without granular or small-fibre fillers, show the lowest impact strength, whereas materials with textile and laminated fillers show higher impact strength. The influence of direction of impact to direction of lamination is considerable.

Thorough investigations on the influence of the resin contents on laminated materials have been carried out by W. Kuech. According to this worker, the influence of resin contents on the properties of the finished product is very important, but changes considerably with the bearer material, i.e., pressed hardwood, cellulose-sheets (thickness 0.6 mm.) and woven textiles (weight 66 gm./sq. m.).

In the case of pressed-wood, the tensile and bending strength, and the modulus of elasticity fall with increasing resin contents. Even in the case of compression strength, in the range between 7-28 per cent. resin contents, a small decrease with increasing resin content could be observed.

Specific gravity is not appreciably influenced by the resin content. High resin content reduces the capacity for absorbing energy in the case of impact bending strength. The advantage of the high resin content in pressed-wood is the imparting of good resistance to moisture so that no other surface protection becomes necessary.

In the case of laminated plastics built up from cellulose sheets, the tensile, compression- and bending strength increase considerably with increasing resin contents, in spite of the reduced compressibility of the material. After the fibres become saturated, a further increase in the resin contents leads to a decrease in strength of the pressed specimen. With too low a resin content, cellulose laminated plastic is more sensitive to moisture than pressed-wood, while increase of the resin content to above 20 per cent. does not materially increase water-resistance.

Laminated plastics with woven textiles behave, in the case of tensile and bending strength, in a manner similar to the cellulose material. The optimum resin content is 33-38 per cent. The compression strength is determined only by the extent of the resin content and increases uniformly with increase of the former. The resistance to moisture is also relatively satisfactory in the case of low resin contents.

By using urea resins instead of phenol resins, some improvements in physical properties could be obtained. Table 5 shows how the tensile strength of the untreated material was increased through the treatment with resin, and the pressing process.

The resin content and the conditions of the filler are

Table 6.—Influence of moulding conditions and their consequences on the working conditions (according to Roehrs-Krahl).

No.	Condition	Degree of flow	Hardening property	Moulding time
1	Moulding pressure			
	Increased	Increased	Unchanged	Increased
	Reduced	Reduced	Unchanged	Increased
2	Optimum moulding temperature	Maximum value		
	Surpassed	Reduced	Increased	Increased
	Not attained	Reduced	Reduced	Increased
3	Preheating of the mass			
	Correct (medium)	Increased	Increased	Reduced
	Too much	Reduced	Increased	Increased
4	Grain size of the plastic material			
	More coarse	Unchanged	Unchanged	Increased
	More fine	Unchanged	Unchanged	Reduced
5	Condition of the raw material			
	Moist	Increased	Reduced	Reduced
	Dry	Reduced	Increased	Increased
6	Resin-content			
	Increased	Increased	Unchanged	Without great effect
	Reduced	Reduced	Unchanged	

but two of the factors which influence the moulding process and the strength of the mass obtained, therefore it may be helpful to consider them together with other factors which influence the moulding technique, such as pressure, temperature and pre-heating conditions of the material (moist or dry).

From Table 6 it will be seen that grain size and resin-content exert only a subordinate effect on moulding technique.

Such a summary as this is certainly open to some criticism. For instance, in many cases, degree of flow will be influenced by the grain size and, further, the resin content will influence moulding time, but, considered from a general point of view, it will be found that Table 6 covers all average cases.

It has been shown by Houwink how great a degree the flow and the moulding pressure are influenced by the resin contents or the resin-filler ratio. As the flow of the mass usually increases with higher resin contents, the moulding time will eventually be reduced; this is clearly shown in Table 2 according to tests by Krahl, which further show some striking differences between phenol and cresol resins.

Micro-structures of Resin/filler Masses

Any physical and technological tests, for instance, tensile strength, bending strength, indentation hardness (micro-hardness tests excluded), can give only an average figure for the material. In order to gain information on its constitution, it is necessary to study the relevant microstructure, to determine how the particles unite and their regular or irregular distribution throughout the body of the moulded part, in particular, near the surface.

This special information can be obtained in no other way, and it is to be presumed that the microstructures of plastics will, one day, be as important to the investigator as similar studies in metallurgy. Not only is it possible to explain, by their aid, differences in the physical properties of different kinds of plastics, but the producer is given the possibility of controlling structure and of finding one or another way to improve his product, for instance, by planned changes in mixing, mixing time, moulding time, temperature of mould, etc. (see also factors given in Table 4).

Some practical results with regard to the distribution of fillers in the surface of wood-filled plastics have been

obtained by W. Weigel. It is usually assumed that the surface of plastics, having a high lustre, is formed by a very thin film of pure resin. There is the possibility that this layer may form a skin, or that the amount of filler may increase progressively from the surface. Weigel (V.D.I. 1937) found the thickness of the upper film, having no filler, to be between 0.025 mm. and 0.04 mm. in the case of components of greater wall thickness.

To determine the distribution of filler in succeeding layers, Weigel etched the surface for periods of $\frac{1}{8}$, 1,

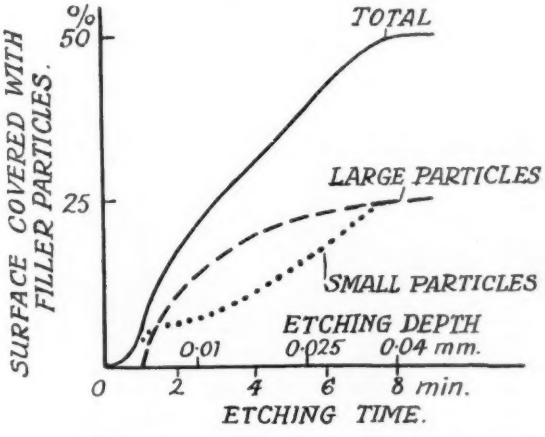


Fig. 3.—Surface covered with filler particles plotted against etching time.

5 and 30 mins. with a concentrated solution of methylene blue in concentrated sulphuric acid. He draws the following conclusions: The extreme surface layer consists of practically pure resin which contains only dust and similar small particles. Then follows a zone in which the particles are in the majority, large.

After a longer etching period, the structure assumes that of the inner body, i.e., smaller and larger particles cover nearly equal surfaces. Fig. 4 shows the results of a large number of tests, average estimated values being given. This graph shows also that thin sections, the thickness of which lies usually between 0.01 mm. and 0.04 mm., will yield surfaces with a majority of large particles, thus giving a false picture of both the surface and the inner body of the mass.

The same author tested flash (from moulds) with a thickness between 0.2 mm. and 0.5 mm.; this obviously has special properties with regard to thickness and structure. Etchings demonstrated that it had very much higher resin contents than components of greater wall thickness. The extreme layers contained a far smaller amount of the filler material, and the smaller particles were in majority. The filler distribution was of great irregularity, comparable with the known phenomenon of bridge formation in the case of dust agglomerates.

Influence of Flow in the Mould

The flow in the mould has considerable influence on the filler distribution. Weigel carried out tests with so-called flow-control discs consisting of annular grooves in two discs, between which the plastic material is pressed; the number of pressed-out rings, or the diameter of the resulting disc, represent a measure of the degree of flow.

In one case, the extreme (of six rings) remained incomplete and showed at its end a strip of up to $\frac{3}{4}$ in. width which was rough, without polish and brittle;

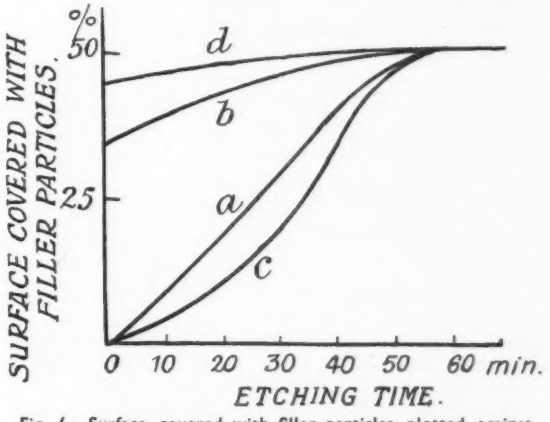


Fig. 4.—Surface covered with filler particles plotted against etching time for two different plastics in flow control discs.
Mass A .. (a) ring 0 to 5
(b) ring 6
Mass B .. (c) ring 0 to 4
(d) ring 5

structural and chemical tests revealed that this part consisted mainly of wood flour. The centre and the extreme ring, apart from the end portion, showed an accumulation of filler particles. It can be assumed that this process of separation is caused by the flow of the fluid mass in the mould. In particular, the larger particles which were present in the outside ring seemed to be "floating" in front of the fluid resin. The intermediate rings contained fewer filler particles and were similar in their structure.

Similar conditions such as prevailed in these discs have been found on a test cup. Whereas the lower edge showed some lack in filler particles, on the upper edge filler particles which floated in front of the resin mass could again be found.

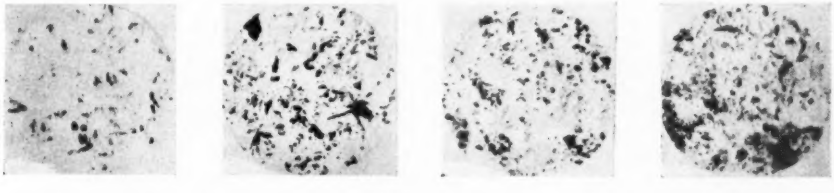


Fig. 5.—Surface etching to progressive depths.

Influence of Pressing Time

Tests reveal that, in the case of reduced moulding time (higher pressing speed), the process of separation of filler becomes more evident. Flow degree discs produced in a longer pressing time showed a greater uniformity, as the longer particles could not adjust themselves in the direction of flow. The phenomenon of a pallisade accumulation perpendicular to the direction of flow could not be observed.

Inquiries and Answers

(In Which is Included General Correspondence)

IMPORTANT NOTICE: If inquirers wish to receive replies by post, a stamped and addressed envelope must be included in their letter. It is understood that the submission of a problem to the Editor permits its publication in this journal.

Transparent Mouldings

Could you favour us with a reply on the following question? We seek information as to whether there is available a moulding powder which will give a transparent finished product, which would also permit of boiling for sterilization. RAWLINGS MFG. CO., LTD.

London, S.W.

[EDITOR'S NOTE.—The only transparent thermo-hardening moulding powder we know is a urea-formaldehyde resin made by British Industrial Plastics, Ltd. We have made mention of its use in past issues for making transparent fuse-boxes, etc. Urea resins have been suggested for the production of surgical trays, etc., but we believe that the mouldings will not withstand repeated sterilization by boiling. A means of sterilization other than by boiling has been suggested. This information is over two years old, so that British Industrial Plastics, Ltd., may have more recent data.]

Isolumen

I was very interested to read your article in the October issue of *Plastics* on Isolumen.

Is it possible for you to send me a piece of this to have a look at it, or could you tell me where I can buy it, and the price, as I should rather like to have it installed in my printing factory. C. GEORGE.

I was extremely interested to read the article on Isolumen, published in your October issue, and would be glad if you would put me in touch with the manufacturers with a view to obtaining a sample and costs. SAM BUNTON, A.R.I.A.S., M.Inst.R.A.

Glasgow.

[EDITOR'S NOTE.—We understand that full-scale manufacture of Isolumen has not yet been reached. All inquiries should be addressed to Pharaoh Gane and Co., Ltd. (Isolumen Dept.), Adelaide House, King William Street, London.]

Transparent Oven Doors

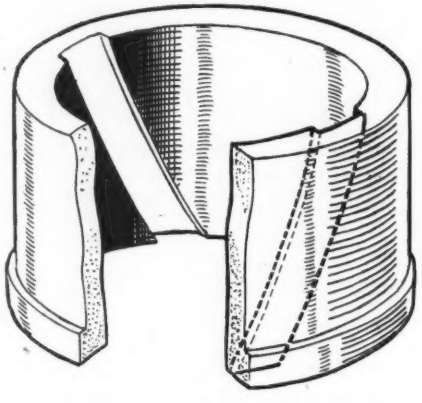
As subscribers to your publication, we should be pleased to know if it is possible to get a transparent plastic suitable for making oven doors for domestic cookers. The temperature would be approximately 800 degrees Fahrenheit and the material should stand this without any effect, coloration or distortion.

Birmingham, 12. TURLEY AND WILLIAMS, LTD.

[EDITOR'S NOTE.—We fear that no plastic is, nor is ever likely to be, suitable for the purpose. We know of no organic body that is not destroyed, physically or chemically, at this temperature. What is wrong with the boron glasses as typified by Pyrex? Although they are fragile, and we presume this is the crux of the matter, oven engineers should design a door which should be able to protect the glass and allow of its rapid replacement. Plastics are not panaceas for all industrial ills.]

Motorcycle Bush

We are sending you under separate cover a bush made of some plastic material taken from a part of a German motorcycle, and we shall be much obliged if



you can advise us what the material from which these parts are made is called, and advise us as to who is most likely to be able to supply us with this in this country. ASSOCIATED MOTOR CYCLES, LTD.

London, S.E.18.

[EDITOR'S NOTE.—Without much doubt, the bush is moulded from a phenol-formaldehyde moulding powder and most probably a "high-strength" one. The best procedure for the inquirers would be to approach one or other of the moulding concerns mentioned in our Directory (page IV) and obtain their advice and co-operation as to the most suitable powder to employ. For general information, the internal diameter is $1\frac{3}{8}$ ins. and the smallest wall thickness is about $\frac{7}{32}$ in. As we presume this would be a job for Government motorcycles, there would be no trouble regarding supply of raw material.]

Books

The following three books were mentioned in the correspondence section of September *Plastics*. Can you tell me if they are obtainable in this country anywhere?

1. "Plastics in the Home and School Workshop."
2. "Plastics—Problems and Processes."
3. "Plastics in Engineering."

Bristol, 6. H. CARL MARTIN.

[EDITOR'S NOTE.—We do not know the English publishers of these books, but, without doubt, you could get them from Lewis's Technical Library, 136 Gower Street, London, W.C.1.]

TRADE AND PERSONAL NOTES

Interior lighting of factories is the subject of new Draft Regulations under the Factories Act issued by the Minister of Labour. The following are the main points in the Regulations, which should be studied for complete details.

1. Subject as in these Regulations provided, these Regulations shall apply to factories in which persons are being regularly employed in a process or processes for more than 48 working hours a week, or in shifts.

2. (a) The general illumination over those interior parts of the factory where persons are regularly employed shall be not less than 6 foot-candles measured in the horizontal plane at a level of 3 ft. above the floor.

(b) The illumination over all other interior parts of the factory over which persons employed pass shall when and where a person is passing be not less than 0.5 foot-candles measured at floor level.

(c) The standards specified in this regulation shall be without prejudice to the provision of any additional illumination required to render the lighting sufficient and suitable for the nature of the work.

3. (a) Where any source of artificial light in the factory is less than 16 ft. above floor level, no part of the source or of the lighting fitting having a brightness greater than 10 candles per square inch shall be visible to persons whilst normally employed within 100 ft. of the source, except where the angle of elevation from the eye to the source or part of the fitting as the case may be exceeds 20 degrees.

(b) Any local light, that is to say an artificial light designed to illuminate particularly the area or part of the area of work of a single operative or small group of operatives working near each other, shall be provided with a suitable shade of opaque material to prevent glare.

(c) So far as reasonably practicable, arrangements shall be made, by suitable screening or placing or other effective method, to prevent discomfort or injury by the reflection of light from smooth or polished surfaces into the eyes of the worker.

4. Adequate measures shall be taken, so far as reasonably practicable, to prevent the formation of shadows which cause eyestrain or risk of accident to any person employed.

5. (a) Where the Chief Inspector of Factories is satisfied in respect of any particular factory or part thereof or in respect of any description of workroom or process that any requirement of these regulations is inappropriate or is not reasonably practicable, he may by certificate exempt the factory.

An explanatory memorandum, which includes tables giving approximate lamp sizes necessary at various heights and spacings, is being sent to employers.

The British Standard Institution has recently issued a War Emergency British Standard No. 919 for Screw Thread Gauge Tolerances. We are advised that the tolerances recommended in this specification were formulated in co-operation with the National Physical Laboratory, and during the period of the war the National Physical Laboratory has agreed to test screw gauges in accordance with this British Standard in cases where it differs from the current practice of the laboratory, unless specially instructed otherwise.

Erinoid, Ltd., have declared a dividend of 6 per cent. A great improvement in results has been maintained, the figure announced disclosing that the trading profit has increased from £15,000 to £51,480.

Ellison Insulations, Ltd., announce that, owing to expansion of business, it has been found necessary for the offices of their Midland Area Engineers to be transferred from the works to 36, Bennetts Hill, Birmingham, 2 (Telephone, Central 5651 (two lines), telegrams " Ellison Phone Central 5651"), on and after Monday, November 4. Inquiries regarding Tufnol from users in the Midland area should be sent to the new address.

The Fredk. Crane Chemical Co., Ltd., has gone into voluntary liquidation and in future will trade under the name of I.C.I. (Paints), Ltd. It will be remembered that in April this year it was announced that Nobel Chemical Finishes, Ltd., would henceforward be known as I.C.I. (Paints), Ltd. The Fredk. Crane Chemical Co. were established in Birmingham as manufacturers of nitro-cellulose lacquers in 1887. With their products cold lacquering became possible in place of the hot lacquering process previously applied to metal articles in order to prevent them tarnishing. In 1912 the company moved to larger premises at Bordesley Green, and in 1937 opened a modern paint factory at Smethwick. As the Fredk. Crane Chemical Co., Ltd., was a subsidiary company of I.C.I. (Paints), Ltd., the two companies are now merged completely, without change of personnel or policy.

Markets in Brazil is the subject of an interesting article in the November issue of the "Chamber of Commerce Journal." With the German and Italian exports to South America now cut off, the opportunities opening up for British exporters are greater than ever. Of exports of special interest to the plastics and allied industries there are those which are products of the rubber and allied-to-rubber industries in the form of belting, hose and dipped goods, miscellaneous goods such as spectacle frames, goggles and sun glasses, clocks of the cheaper variety with plastic frames or mountings, dolls and toys of the block type. The latter in plastics are especially welcomed because of the low weight, and consequent lower carriage rates.

Mr. F. J. Robinson, manager of the Birmingham works of Bakelite, Ltd., completed 25 years' service with the Damard Lacquer Co. and Bakelite, Ltd., on September 23 last. Mr. Potter, on behalf of the directors of the company, presented Mr. Robinson with a gold hunter watch and Mr. Lloyd, on behalf of his colleagues, presented him with a silver cigarette box and four silver ashtrays to commemorate the occasion.

We hear that **Mr. T. J. Fielding,** of the publicity department of Bakelite, Ltd., has recently been made a Captain. Mr. Fielding joined the Officers' Supplementary Reserve about six months before war was declared and did three weeks' training at Catterick during the summer of 1939. He was called up immediately at the outbreak of war and continued his training in North Wales. Captain Fielding is now at G.H.Q., Home Forces.

Dr. H. J. Stern and W. H. Stevens, the well-known rubber consultants, have moved into offices at 214, Great Portland Street, London, W.1. Telephone number is Euston 4090.

Rotas Industries Bakelite Factory, Bombay, being an enemy concern, is the subject of a recent note. All property in British India belonging to it or managed on behalf of it is vested in the Custodian of Enemy Property for British India.

Changes of Address

The British Aluminium Co., Ltd.—This company's temporary head office address is now Oakley Manor, Belle Vue, Shrewsbury, Shropshire. The telegraphic address, " Cryolite Shrewsbury," and telephone number, Shrewsbury 4451, are unchanged (telephone number for Sales, Planning and Publicity Departments, Shrewsbury 4474).

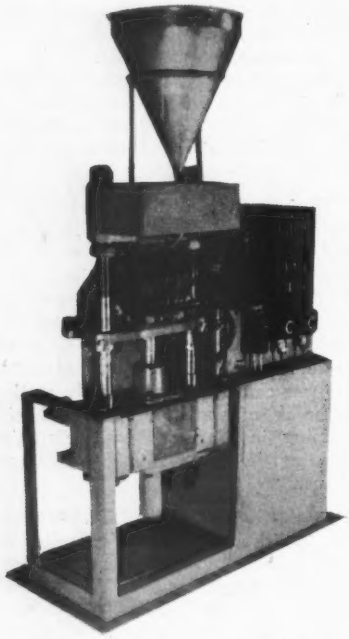
L.R.B. Pearce, Ltd.—The address of this company is now 25, The Chine, Grange Park, London, N.21. Telephone: Laburnum 3505; telegraphic address, Ellarbepea, Winchmore, London.

NEW MATERIALS—NEW PLANT—NEW METHODS

Automatic Moulding Press

We have received an interesting pamphlet from the Cropp Engineering Division of the Warren Lamp Co., Warren, Pennsylvania, describing the 12-ton Cropp completely automatic moulding press. Some of the advantages claimed by the makers are as follow:—

1. Completely automatic. Once the operations have been timed the press repeats each operation to a split second and for hour after hour it continues to make perfect mouldings until



the weighing device discovers an imperfect one, stops the machine automatically and rings for the foreman.

2. Low mould cost. Inasmuch as one cavity will do the work of much more costly multiple cavity moulds, the mould cost is a fraction of what it would be if the work were being done on a conventional-type press. A mould will often cost only 10 per cent. as much as a hand-operated multiple mould yet produce as much because of the efficiency of operation and absence of delay.

3. Continuous operation. Three shifts of eight hours each is not unusual nor impossible on Cropp presses.

4. Self-contained. Cropp presses are complete moulding plants in themselves with no auxiliaries required, except an air source of about 100 lb. pressure.

5. Minimum flash loss. Automatic and accurate measuring of the moulding powder saves as much as 50 per cent. of flash losses over hand operations.

6. Accurate curing. A Microflex, which is accurate to a quarter of a second, assures that each piece is uniformly cured—resulting in a minimum of rejects.

7. Automatic breathing. Standard Cropp presses are complete with a control for automatic breathing, which relieves the mould of vapours which might cause gas-weakened mouldings. Breathing often saves up to 45 per cent. of the entire cycle and naturally increases output per cavity per hour.

New Plant

The General Electric Co. has just published a new 20-page booklet entitled "Electronic Devices for Industry" (GES-2411). Since electrical engineers first put vacuum tubes "in overalls" a few years back the industrial application of devices utilizing these tubes has grown so unobtrusively (and steadily) that it is quite surprising to-day to discover the number of such devices available and the extent of their use throughout industry. The booklet briefly lists some of the more important vacuum-tube apparatus and describes its application and method of operation. An idea of the scope of the little pocket-size publication can be gathered from the fact that it deals with such a variety of devices as photo-tubes, d.-c. motor control, the recording spectrophotometer, exposure meters, pyrometers, gas-discharge and high-vacuum electronic tubes, the Reactrol system, automatic arc-welding equipment, ignition rectifiers, resistance welding and battery-charging equipment.

Imperial Chemical Industries are introducing a simplified technique for the processing of their synthetic denture base, "Kallodent," to meet war-time needs. "Kallodent," the first of the synthetic resins used for dentures, has for four years been successfully processed by injection moulding. Now, in order to bring it within the scope of every dental workshop as well as laboratory, Imperial Chemical Industries are substituting "Kallodent" 222 in powder and liquid form. The correct proportions of powder and liquid for a complete denture are packed separately in each "Kallodent" 222 unit and the two are mixed to form the dough with which denture moulds can be packed. The application of heat completes the solidification of the denture.

The new technique, which can be carried out in standard dental laboratory equipment, has been tested thoroughly and approved by leading dental practitioners throughout the country. It is suitable for use by any competent dental mechanic. Moreover, it is a virtue of this necessary war-time adjustment that it permits of greater economy of material.

"Kallodent" 222 possesses the same essential properties as the original product: resistance to bacterial growth, lightness and immunity from change of colour and dimensions.

Vacuum Relief Valve

Many firms employing vacuum vessels or receivers find it necessary to vary the degree of vacuum from time to time. The most effective method is by fitting an adjustable vacuum relief valve, and B.E.N. Patents, Ltd., of High Wycombe, have produced a valve specially designed for this purpose. The B.E.N. adjustable vacuum relief valve can be readily set to maintain a vacuum at any figure required from 4-in. to maximum. The valve is extremely sensitive and the necessary adjustments to determine the vacuum at which it operates are easily and speedily made. The system on which the B.E.N. valve operates can be briefly described as follows:—

The valve incorporates a piston which is held in position by an adjustable spring. When a predetermined degree of vacuum is reached the resistance of the spring is overcome and the movement of the piston exposes two ports through which air is admitted to the vacuum vessel. As soon as the vacuum is established at its correct value the piston reseats in its original position. Settings providing an infinitely variable degree of vacuum can be secured by adjusting the tension of the spring. The B.E.N. vacuum relief valve is a sturdily constructed item of equipment, and apart from the phosphor bronze spring, gunmetal is employed throughout, thus resisting corrosion.